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CHARACTERIZING MICROWAVE PROPAGATION USING THE AFGL MICROWAVE ATTENUATION/TRANSMITTANCE/BRIGHTNESS TEMPERATURE CODE

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A basic research program is described to investigate weather effects on microwave sensors used in remote sounding and to enhance our knowledge of microwave propagation through clouds and precipitation. In this report, we describe the current RADTRAN algorithm, enumerate its deficiencies, and provide corrective solutions. The latter include: (a) updating the code structure providing user friendly menus and internal comments, (b) providing for consistency with standardized input model atmospheres currently implemented within other AFGL transmission/radiance models, (c) undertaking a comparison of the current algorithm with contemporary state-of-the-art transmittance/radiance codes to insure its fidelity and representativeness, (d) enhancing RADTRAN to treat multiple scattering, (e) providing calculations of polarized surface emissivities based on user specified surface types, and (f) document the code. Finally, we describe appropriate statistical retrieval schemes for inclusion in the code so that users can perform sensor simulation/retrieval studies.

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1. INTRODUCTION

Instrument technology developments and the desire for "all weather" capabilities have contributed to an increased interest in the design and deployment of microwave and millimeter wave communications and sensor systems. Nowhere is this trend more apparent than in the meteorological sensor complement of the current Defense Meteorological Satellite Program (DMSP) Block 5D-3 which consists of three microwave instruments, the SSM/T temperature sounder, the SSM/T-2 moisture sounder, and the SSM/I imager (Isaacs et al, 1986; Falcone and Isaacs, 1987). The follow-on system to the operational TIROS sounding system the ATOVS (Advanced TIROS operational vertical sounder) will also have a microwave/millimeter wave component, the AMSU (Advanced microwave sounding unit). There is also increased interest in ground based microwave sensor systems and in the application of microwave/millimeter wave sensors for airborne surveillance. These developments emphasize the need for an accurate, readily available microwave transmittance, attenuation, and brightness temperature code for Air Force and other Department of Defense users.

The present RADTRAN code has been widely applied within the DoD and elsewhere to provide the capability to perform sensor simulation studies for satellite borne and ground based microwave and millimeter wave systems. In the course of our own remote sensing related research, AER investigators have had the opportunity to successfully apply the RADTRAN model in a variety of contexts. Most recently, for example, we have studied the effect of clouds on millimeter wave moisture soundings using a modified version of RADTRAN for our sensor simulations (Isaacs and Deblonde, 1987).

Our experience has indicated that RADTRAN, in its present form, suffers from a number of minor deficiencies which decrease its general applicability and user friendliness. To circumvent these problem areas, we have developed specific solutions for application to our in-house RADTRAN-based calculations. The approaches which we have adopted are relevant to applications of the general user and, therefore, we believe would significantly enhance the potential of the algorithm for general use.

In this report we describe the physical basis of these enhancements and their implementation in the RADTRAN algorithm in detail. We describe the current RADTRAN algorithm, enumerate its deficiencies, and our enhancements to the RADTRAN algorithm to: (a) update the code structure providing user

friendly menus, internal comments, and ANSI standard FORTRAN 77 coding, (b) provide for consistency with standardized input model atmospheres currently implemented within other AFGL transmission/radiance models, (c) undertake a comparison of the current algorithm with contemporary state-of-the-art transmittance/radiance codes to insure its fidelity and representativeness, (d) enhance RADTRAN to treat multiple scattering, (e) provide for internal calculation of polarized surface emissivities based on user specified surface types, and (f) document the code. Finally, we include appropriate statistical retrieval schemes so that users can perform sensor simulation/retrieval studies if desired.

2. BACKGROUND

The RADTRAN computer code was developed by the Air Force Geophysics Laboratory (AFGL) to provide atmospheric attenuation and brightness temperature calculations for typical atmospheric paths over the frequency range from 1 to 300 GHz (Falcone et al., 1982). This code has been utilized and tested against experimental data for frequencies up to 1000 GHz. RADTRAN provides a design tool which can readily be used to assess potential environmental impacts on microwave and millimeter wave sensors. The atmospheric attenuation submodels of the clear atmosphere, fog, cloud, and rain used in RADTRAN have been thoroughly documented (Falcone et al., 1979). At the frequencies of interest, clear sky absorption is due primarily to water vapor and oxygen (Waters, 1976). Ozone also absorbs in this region, but it generally has a negligible effect on brightness temperature simulations of defense and commercial interest. The absorption of water vapor in RADTRAN is evaluated using the expression of Barret and Chung (1962) for frequencies less than 60 GHz. For frequencies between 60 and 300 GHz the absorption is evaluated from the 183 GHz line plus the nonresonant background using the model of Gaut and Reifenstein (1971). At higher frequencies, water vapor absorption is modeled using the Van Vleck-Weisskopf (1945) line shape, a set of 54 rotational lines (see Table 1) and the Van Vleck frequency fitting to the continuum. A more recent model is the Gaut-Reifenstein continuum which provides an adequate model at moderate relative humidities (Liebe and Layton, 1983) but has questionable temperature dependence (Burch, 1981). Oxygen absorption is evaluated using the parameters of Meeks and Lilley (1963). The effects of line coupling at 60 GHz (Rosenkranz, 1975) are included as an option in the current RADTRAN code. Many of these expressions are summarized in Falcone et al. (1971).

The current RADTRAN code calculates constituent dependent attenuation (e.g. oxygen, water vapor, clouds, rain), total attenuation, transmittance, and brightness temperature as functions of frequency and atmospheric, surface, and spectral input data. The brightness temperature calculation is based on evaluation of the radiative transfer equation for thermal emission (i.e. neglecting scattering sources) of microwave frequencies:

$$T_{b\nu} = [\epsilon_S T_S + (1 - \epsilon_S) \int_o^{p_s} T(p) d\tau'_\nu] \, \tau_\nu(p_S) + \int_{p_S}^{o} T(p) d\tau_\nu \tag{1}$$

where

$$\tau_\nu(p) = \exp \left[- \int_o^p k\,(\nu, p')dp'/\mu\right] \tag{2}$$

and

$$\tau_\nu'(p) = \exp \left[- \int_p^{p_s} k(\nu, p')dp'/\mu\right]. \tag{3}$$

Here, T_B is the brightness temperature, μ is the cosine of the path zenith angle, and τ_ν and τ'_ν are the upward and downward transmission functions, respectively. Dependence on the temperature profile, surface temperature and surface emissivity are explicit in the above expression. Dependence on relevant constituent abundances (such as oxygen and water vapor) and spectral line shape parameters are implicit in the evaluation of the transmittance functions (Equations 2 and 3) through the absorption coefficients. These parameters are also functions of temperature and pressure. The surface emissivity, ϵ_s is chosen for surfaces of interest or calculated by the Fresnel equations.

RADTRAN also provides a capability to include the attenuation of cloud, fog, and rain in the evaluation of atmospheric transmittance. These models are described in Falcone et al. (1979). The cloud and rain subroutines, GMFOG and GMRAIN, respectively, provide cloud models which are largely based on the data of Silverman and Sprague (1970). Cloud attenuation is evaluated using the Rayleigh approximation and the mass density of the selected cloud model. Complex index of refraction data for water clouds is taken from Ray (1972).

Table 1. Water Vapor Rotational Line Parameters

Transition	Frequency	Parity	Matrix	Energy Levels		Linewidth		x
5,23-6,16	22.2352	EOOE	.0549	446.39	447.17	.09019	.4777	.626
2,20-3,13	183.3101	EEOO	.1015	136.15	142.30	.09600	.4937	.649
9,36-10,29	323.1585	OEEO	.087	1283.02	1293.80	.07652	.4012	.42
4,22-5,15	323.7581	EEOO	.0891	315.70	326.50	.09292	.5071	.619
3,21-4,14	377.4180	EOOE	.1224	212.12	224.71	.09480	.5280	.63
11,210-10,37	389.7088	EEOO	.068	1525.31	1538.31	.0702	.3807	.33
6,60-7,53	435.8743	EEOO	.082	1045.14	1059.68	.0500	.2648	.29
5,50-6,43	437.6730	OEEO	.0987	742.18	756.78	.059	.348	.36
6,61-7,52	441.5700	EOOE	.082	1045.14	1059.87	.05023	.2709	.332
3,30-4,23	445.7669	OEEO	.1316	285.46	300.33	.08247	.4748	.510
5,51-6,42	465.8519	OOEE	.0990	742.18	757.72	.0629	.3521	.38
4,40-5,33	470.9481	EEOO	.1165	488.19	503.90	.0690	.3987	.38
7,17-6,24	487.136	OOEE	.033	586.46	602.71	.0861	.4926	.51
7,70-8,63	498.5275	OEEO	.077	1394.96	1411.59	.0424	.2051	.32
7,71-8,62	498.5275	OOEE	.072	1394.96	1411.59	.0424	.205	.34
1,01-1,10	557.5834	EOOE	1.5000	23.76	42.36	.11115	.4889	.645
4,41-5,32	617.8383	EOOE	.1193	488.19	508.80	.07606	.4262	.60
8,80-9,73	641.5206	EEOO	.066	1789.36	1810.76	.0380	.172	.40
8,81-9,72	641.5206	EOOE	.066	1789.36	1810.76	.0380	.1715	.40
2,02-2,11	752.7375	EEOO	2.0739	70.08	95.19	.10440	.4648	.69
8,35-9,28	833.0775	OOEE	.157	1052.72	1080.51	.0798	.4297	.51
11,29-10,56	857.9589	EOOE	.067	1690.74	1719.36	.055	.309	.20
9,90-10,83	859.1580	OEEO	.059	2225.87	2254.53	.0357	.1535	.48
9,91-10,82	859.1580	OOEE	.059	2225.87	2254.53	.0357	.1535	.48
3,31-4,22	912.5181	OOEE	.1613	285.26	315.70	.08638	.4689	.676
4,31-5,24	961.3816	OOEE	.2622	383.93	416.00	.08262	.4722	.56
1,11-2,02	987.4621	OOEE	.7557	37.14	70.08	.10316	.5069	.660
12,211-11,38	1077.3949	EOOE	.042	1774.85	1810.79	.061	.3476	.25
3,03-3,12	1098.3793	EOOE	.1809	136.74	173.38	.09944	.5590	.701
10,29-9,55	1107.6723	EEOO	.050	1438.19	1475.14	.061	.631	.25
0,00-1,11	1113.3681	EEOO	1.0000	0.00	37.14	.10034	.5026	.689
10,100-11,93	1142.7461	EEOO	.054	2702.61	2740.73	.03434	.1297	.503
10,101-11,92	1142.7461	EOOE	.054	2702.61	2740.73	.03434	.1297	.503
8,18-7,25	1145.7439	OEEO	.025	744.20	782.42	.08008	.4563	.498
2,21-3,32	1154.1376	EOOE	.3003	134.88	173.38	.09515	.5485	.61
5,41-6,34	1159.8333	EOOE	.2784	610.34	649.03	.07131	.4229	.399
3,12-3,21	1161.3322	OEEO	2.5434	173.38	212.12	.09487	.5060	.682
7,61-8,54	1163.4307	EOOE	.223	1216.38	1255.19	.0516	.2908	.29
6,51-7,44	1169.7260	OOEE	.252	888.74	927.76	.0648	.374	.36
7.62-8,53	1187.1130	EEOO	.223	1216.38	1255.98	.0542	.3061	.30
8,71-9,64	1208.9966	OOEE	.199	1591.11	1631.44	.0445	.2381	.32
8,72-9,63	1213.1935	OEEO	.199	1591.11	1631.58	.0447	.2411	.34
4,13-4,22	1213.1935	OOEE	3.6547	272.23	315.70	.09507	.5091	.72
2,11-2,20	1227.8825	OOEE	1.2594	95.19	136.15	.09792	.4658	.67
6,52-7,43	1227.9451	OEEO	.253	888.70	931.33	.0688	.2682	.45
7,34-8,27	1294.4328	OEEO	.184	842.51	885.69	.0819	.4577	.55
9,18-8,45	1309.7213	OEEO	.047	1079.20	1122.89	.060	.348	.25
5,32-6,25	1323.2113	OEEO	.3117	508.80	552.94	.08313	.4939	.571
9,81-10,74	1329.8063	EOOE	.173	2010.19	2054.55	.0390	.2077	.39
9,82-10,73	1329.8063	EEOO	.173	2010.19	2054.55	.0390	.2077	.39
8,17-7,44	1342.6967	OOEE	.036	882.97	927.76	.066	.375	.30
5,14-5,23	1407.4483	OEEO	4.2239	399.44	446.39	.09470	.5123	.722
10,19-9,46	1423.3364	OOEE	.059	1293.22	1340.70	.055	.322	.24
6,33-7,26	1435.9270	OOEE	.258	661.54	709.44	.0830	.4642	.59

3. TECHNICAL APPROACH

Although the RADTRAN code already possesses many of the attributes desired of a generally applicable attenuation/transmittance/brightness temperature simulation code for the microwave spectral region, it lacks a number of desirable and potentially useful capabilities. These include the capability to: (a) model frequency dependent, polarized surface emissivity, (b) calculate the scattering properties of precipitation, (c) perform scalar multiple scattering calculations, (d) calculate polarization dependent, multiple scattered brightness temperatures, and (e) perform sensor retrieval simulations. Figure 1 (Isaacs et al., 1985) illustrates the configuration of the completed model including the enhancements alluded to above. The schematic in Figure 1 is annotated along the horizontal axis to define functional subelements in the program corresponding to the topics discussed below. For example, the treatment of precipitation scattering occurs in the segment called physical models, while that for the filter function appears in system response. Treatments of these aspects of code enhancement are discussed below. Additionally, the baseline code has been upgraded to conform to modern programming practices. Finally, we describe the addition of retrieval capability employing statistical retrieval codes developed at AER. This addition to the microwave transmittance/brightness temperature code would be extremely useful for satellite and ground based temperature and water vapor profiling.

3.1 RADTRAN Program Attributes

The existing code is unstructured, for the most part, with the essential calculation contained in a large main program. Subroutines are utilized for cloud properties and evaluating gaseous absorption parameterizations. The code is largely undocumented with some code segments not utilized in the calculation. The important elements of the calculation, i.e., (a) input data files (atmospheric profiles, line spectral data, and supplementary block data); (b) gaseous absorption models; (c) cloud/rain attenuation models; (d) atmospheric layering approach; (e) layer transmittance calculation; (f) radiative transfer calculation; and (g) output formatting, are present. However, efficiency of the code and its understandability can be improved by enhancing the code's modularity following accepted programming practices.

This calls for subroutining, the creation of relevant common blocks, and the elimination of unnecessary looping within the procedure. The code needs to be commented and provided with documentation including relevant test cases.

While the essential elements of the transmittance calculation and radiative transfer code are inherent in the model, the methodology adopted in some of the code procedures should be evaluated in light of recent developments. Some aspects of the gaseous absorption treatment, for example, are twenty years old and require updating or revision. Specific aspects of the gas

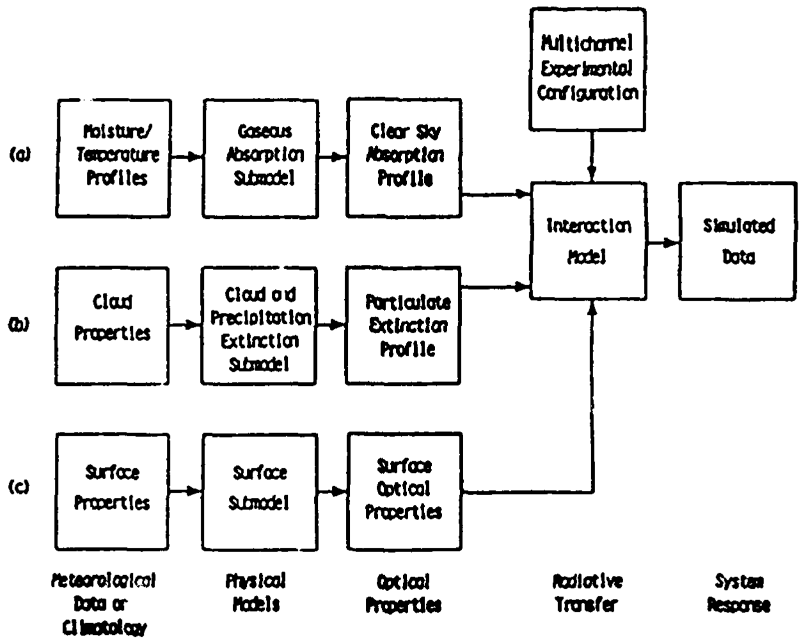

Figure 1. Schematic of proposed microwave transmittance/brightness temperature simulation code.

absorption modeling requiring evaluation include the spectral line data, line shape, pressure broadening coefficients, line coupling approach, and treatment of the water vapor continuum. In light of recent measurements and understanding of the basic theory involved, this is not an unreasonable expectation.

3.2 Frequency Dependent, Polarized Surface Emissivity Models

The RADTRAN code is frequently applied to microwave systems effectiveness simulation studies for both airborne and satellite-based sensors viewing the earth's surface. Such applications require the capability to supplement the atmospheric radiative transfer calculation with realistic models of the microwave properties of the sensor scene field-of-view allowing for variations in polarization and frequency dependence of emissivity due to changes in surface type. Frequently, this information is provided via available empirical data sets. However, the range of available field measurements is limited. In order to facilitate the evaluation of sensor performance throughout a range of pertinent geophysical surface scenarios, deterministic models of microwave surface emission are desired which can be exercised concurrently with the models for atmospheric transmission. To achieve this goal, a set of microwave surface emission models was developed by AER to accompany the RADTRAN atmospheric properties model. In addition to obvious applications to microwave background simulations, application of such models to remote sensing simulation studies can also provide a theoretical basis for understanding of the sensitivity of microwave sensor data to variations in relevant hydrological parameters such as soil moisture, snow, and vegetative moisture content.

The selection of a simple surface modeling approach is made difficult by the complexity of geophysical surfaces. For example, homogeneous dielectric slab models for both land and ocean have been commonly used to provide the required surface emissivity parameters to initiate brightness temperature simulation calculations. It is apparent from an examination of recent microwave satellite imagery that such approaches cannot reproduce the fidelity of the complex fields of observed surface properties. This is due to the neglect of important physical mechanisms such as scattering by such approaches, and their failure to treat the spatial inhomogeneities in dielectric properties due to the inherent physical structures of real surfaces. On the other hand, it is necessary to consider the computational level of effort required to model all of the physics, even if it were well understood.

Related to the choice of an appropriate model, is the detail of surface type characterization desired, i.e. how many surface types to treat. In reality, of course, there is a continuum of geophysical surface types. A sufficiently general model can attempt to simulate some of the behavior exhibited by subsets of surface types within this continuum by choosing appropriate parameterizations of relevant surface properties and varying them within representative ranges. The choice of surface types employed within the proposed RADTRAN surface modeling package was based both on the desire to treat a comprehensive set of surfaces and, to some extent, on the requirements of potential model users with specific surface related simulation applications. The surface types selected are: (a) calm and rough ocean, (b) first year (FY) and multiyear (MY) sea ice, (c) wet and dry snow over land, (d) moist soil, (e) vegetation, and (f) land. The land surface type provides a background for snow, soil, and vegetation models in addition to its potential role as a distinct surface type itself. A menu will be provided to select from among the available surface type choices. Surface types are summarized in Table 2.

Both the calm ocean and land are modeled as simple dielectric slabs. The other surface types, however, clearly require a more sophisticated modeling treatment. As the following discussion will indicate, it is not appropriate to treat all of the surface types delineated above by a single formalism. Therefore, two distinct approaches have been applied in the development of these surface emission models: that based on wave theory for random discrete scatterers and that based on radiative transfer theory for continuous random media The former approach is applied to modeling the ocean surface, sea ice, and snow, while the latter is applied to both soil and vegetation. These approaches are also summarized in Table 2.

In the wave theory approach for random discrete scatterers, one or more layers is defined consisting of a dielectric medium with either uniform properties or containing a random distribution of discrete dielectric spheres with distinct dielectric properties. These latter inclusions give the medium scattering properties which by appropriate choice of the background and inclusion permittivities can be tuned to exhibit the observed behavior of sea ice

Table 2. Surface Model Types and Modeling Approaches

Model	Surface Type	Modeling Approach
1	Calm ocean	Dielectric slab
2	Rough ocean	Random discrete scatterers
3	FY sea ice	Random discrete scatterers
4	MY sea ice	Random discrete scatterers
5	Dry snow	Random discrete scatterers
6	Wet snow	Random discrete scatterers
7	Land	Dielectric slab
8	Wet soil	Continuous random medium
9	Vegetation	Continuous random medium

and dry snow, for example. The radiative transfer approach for continuous random media models the surface from a different perspective. Some surfaces are spatially inhomogeneous in their dielectric properties, yet the inhomogeneities are not due to discrete spherical scatterers. The approach provides an alternative treatment in which the permittivity is varied continuously throughout the medium. Furthermore, these spatial variations are parameterized in such a manner that the relative effects of variations in the vertical and horizontal physical structure of the medium can be modeled. These surface emissivity models are summarized in a recent journal article (Isaacs et al., 1989).

3.3 Scattering Properties of Precipitation

Treatment of precipitation in brightness temperature simulations require the specification of precipitation scattering optical properties including the extinction coefficient, single scattering albedo, and the angular scattering function. These data are not currently implemented within RADTRAN and must be supplied by the user.

Precipitation scattering properties are generally available via standard Mie theory calculations. The Mie theory formalism requires a knowledge of particle size distribution and index of refraction. The index of refraction, in turn, is dependent on frequency, phase (i.e. ice or water), and temperature. To avoid the cumbersome necessity of performing on-line Mie theory calculations to support each possible combination of these model variables

within multiple scenario brightness temperature simulations, a parameterization has been developed based on the existing Mie theory calculations of Savage. This parameterization is available for implementation within RADTRAN. The attributes of the precipitation property modeling subroutine are described in a paper by Isaacs et al. (1989).

The resultant subroutine provides an efficient method to obtain the extinction coefficient, single scattering albedo, and angular scattering function over the frequency domain from 19 to 240 GHz. The angular scattering function is given in terms of its first eight Legendre polynomial expansion coefficients. Precipitation angular scattering functions are not highly anisotropic at microwave frequencies and this number of terms usually suffices to describe them. Furthermore, this number of terms is consistent with the Gaussian quadrature required to specify the brightness temperature field (Savage, 1978). The scattering function asymmetry factor used in standard multiple scattering approximations is easily obtained from a knowledge of the second Legendre coefficient.

3.4 Multiple Scattering

When precipitation is present evaluation of the multiply scattered brightness temperature field requires a generalization of the radiance (i.e. brightness temperature) solution. To generalize the radiance solution, either scalar (i.e. ignoring polarization) or vector (i.e. including polarization) multiple scattering treatments are possible. The scalar approach is appropriate for nadir viewing only and when the atmospheric path and transmittance are such that there are no surface contributions to the brightness temperature field. (Surface emission and reflection can be highly polarized depending on the surface type, viewing angle, and frequency.) We have implemented a scalar multiple scattering approximation into FASCODE based on an approximation of the multiple scattering source function (Isaacs et al., 1987c).

A more complete vector treatment is required in the microwave region, capable of treating the multiple scattering of microwaves by anisotropic, inhomogeneous distributions of liquid or glaciated precipitation. The approach which we implemented uses a numerical, Gaussian quadrature approach to the radiative transfer equation (Jin and Isaacs, 1985). The paper by Jin and Isaacs (1987) illustrates applications of the polarized brightness temperature

calculations to the simulation of precipitation dependent (i.e. parameterized by the rain rate) channel brightness temperatures for the SSM/I microwave imager.

3.5 Retrieval Codes

The RADTRAN data simulation capability would be greatly enhanced by the availability of retrieval codes to perform retrieval simulations for weather parameters of interest such as temperature and moisture profiles, cloud and precipitation. We have used statistical (Isaacs and Deblonde, 1985, 1987) and physical (Isaacs, 1989) retrieval codes for this purpose. These have been reviewed by Isaacs (1988b).

4. INCORPORATION OF ALGORITHM ENHANCEMENTS

The RADTRAN code has been upgraded and modularized by incorporating the capabilities to: (a) evaluate frequency dependent, polarized surface emissivity - a menu driven, user selected surface type solution has been implemented based on the surface emissivity submodels described in Section 3.2. The surface emissivity supports evaluation of surface emitted brightness temperatures; (b) calculate scattering properties of precipitation - The subprogram for calculating precipitation optical properties described in Section 3.3 has been incorporated. This provides the user with frequency dependent values of extinction coefficient, single scattering albedo, asymmetry factor, and the angular scattering function for liquid and glaciated precipitation. These quantities are essential to performing the scalar multiple scattering calculation of brightness temperatures in the presence of precipitation; (c) perform multiple scattering brightness temperature calculations in precipitating conditions: an exact multiple scattering approach for fully polarized brightness temperature calculations has been included as a user selectible option. This option is applicable to the simulation of data from sensors with polarization discrimination; and (d) perform statistical retrievals. The specification of atmospheric profiles has also been generalized to assimilate user specified input profiles. Standard meteorological profile models (e.g. U.S. standard, tropical, etc.) has been augmented by the capability to accept field data, radiosonde and other upper air data, and user specified format profile data as input.

4.1 Algorithm Upgrade

The basic RADTRAN algorithm was modularized and reconfigured for efficiency. A main program called RADTRAN functions as the executive program and calls all other subroutines. (Flowcharts and complete user instructions are given in Section 5, see Figures 2, 3 and 4.) RADTRAN includes a description of file assignments and user input instructions. Input formats were modified for consistency with the general approach adopted in the LOWTRAN/FASCODE environment. A major focus of the algorithm upgrade was the integration of new capabilities to internally calculate surface emissivities from among a variety of surface models, to evaluate both scattering and attenuation properties of precipitation, and to accomplish accurate multiple scattering calculations in the presence of precipitation. Therefore, user input options are provided to flag these capabilities on or off and to default to the original RADTRAN capability, i.e. user input of surface emissivities and no multiple scattering.

RADTRAN calls one of five main subroutines. ATMPRF is called to set up and print out the user specified atmosphere including temperature, water vapor, cloud, and rain profiles. This subroutine controls the options for user supplied, arbitrary format input model atmospheres. Subroutine ATTEN calculates attenuation for the desired path and also evaluates weighting functions if desired. RDTRAN performs the radiative transfer calculation in non-scattering atmospheres. It incorporates the attenuation calculations from ATTEN and the surface reflection/emission either input by the user or calculated from the surface emissivity models. The remaining subroutines incorporate one of the new capabilities cited above and interface with the radiative transfer calculation through RADTRAN, depending on the nature of the options which are toggled by the user.

4.2 Surface Emissivity Enhancement

Section 3.2 provides some background on the internal surface model capabilities which form the basis of this enhancement. The enhanced RADTRAN implementation provides the user with four options related to the treatment of the surface. These are selected by toggling the flag ISRFC in the user input file. The options are:

ISRFC = 0 NO SURFACE USED IN CALCULATION

= 1 INTERNAL MODEL SUPPLIES SURFACE TEMPERATURE AND EMISSIVITY

(NOTE: FOR MODELS 1-4, FREQ MUST BE LESS THAN 35 GHZ)

= 2 USER SUPPLIED SURFACE TEMPERATURE, INTERNAL MODEL PROVIDES EMISSIVITY

= 3 USER SUPPLIED SURFACE TEMPERATURE AND EMISSIVITY

Option 1 (ISRFC=0) is self explanatory, i.e. no surface is used in the calculation of brightness temperature. This implies no surface emission and no reflection of downward brightness temperature contributions. Option 2 (ISRFC=1) selects one of the model surfaces described briefly in Section 3.2 (see Table 2). The surface modeling subpackage is contained in subroutine SRFMOD and its associated subroutines. The surface model selected is toggled by the flag. Depending on the model selected a variety of input parameters may be required. These are described in the input file description contained in Section 5.2. Note that subroutine SRFMOD can be removed from the RADTRAN code and run offline if it is desired only to calculate polarized surface emissivities. In Option 3 (ISRFC=2), the user can take advantage of the ability of the internal surface model subpackage to provide results for varying surface related input parameters. The most common surface related parameter is the surface temperature. In Option 2, the surface temperature used in the surface emissivity calculation is chosen to match that of the lowest model layer of the user selected input atmosphere. In Option 3, the user can select the surface temperature independently of the atmospheric input. Option 4 (ISRFC=3) provided continuity with the basic RADTRAN code and requires that the user supply both the surface temperature and the surface emissivity.

The surface dependent model parameters for the various surface models include sea ice thicknesses and scattering inclusion size, snow depth and wetness, soil moisture, and vegetative moisture and thickness. Individual users may want to vary these quantities as required for their own simulations requirements.

4.3 Scattering Properties of Precipitation Enhancement

The basic RADTRAN provided the capability to evaluate the attenuation properties of precipitation, however, since scattering was not included in the brightness temperature calculation, no provision was made to treat precipitation scattering properties. In the enhanced RADTRAN, we have included the option of printing out a table of precipitation scattering properties based on the approximation described by Isaacs et al. (1988). The coding for this function is contained in subroutine SCAT. These properties include the absorption coefficient, the extinction coefficient, and the first eight Legendre polynomial coefficients of the expansion of the angular scattering distribution as functions of frequency, rainrate, temperature phase, and size distribution (either Marshall-Palmer or Best). These properties can be used directly to drive a simple scalar (i.e. unpolarized) multiple scattering calculation of brightness temperatures in the presence of precipitation using, for example, a discrete ordinate multiple scattering algorithm such as that described by Liou et al. (1980). They are also of interest themselves as a means to characterize potential scattering effects and contributions to the brightness temperature field before multiple scattering calculations are performed, e.g. by examining the magnitude of the single scattering albedo. Note that these properties are not used directly in our multiple scattering enhancement (Section 4.4) since we require a fully polarized brightness temperature calculation.

4.4 Polarized, Multiple Scattering Enhancement

Jin and Isaacs (1985,1987) describe a discrete ordinate radiative transfer code for the evaluation of polarized microwave brightness temperatures in the presence of precipitation. The approach is applicable to realistic precipitation distributions with varying vertical properties (i.e., inhomogeneity) such as height dependent rain rates and rain phase (ice/water) such as those which comprise the RADTRAN rain models. The previous version of RADTRAN had no capability to calculate brightness temperature fields in the presence of precipitation due to the lack of a treatment for multiple scattering. (Resulting brightness temperatures including rain attenuation simply treated rain as an equivalent absorber thus failing to simulate several important scattering mechanisms.)

The enhanced RADTRAN incorporates multiple scattering in a self consistent manner and integrates it with both the gas attenuation modules of the original RADTRAN (in subroutine ATTEN) and the new surface modeling capabilities (in subroutine SRFMOD). The multiple scattering capability is toggled on by the user by the IMS input flag. Gas absorption coefficients from ATTEN are input to the multiple scattering code and combined with an internal calculation of the rain dependent scattering and absorption coefficients to produce a layer dependent single scattering albedo profile. The phase matrix elements as a function of rain rate are also calculated internally. All rain extinction and scattering properties are driven by the user specified precipitation rain rate/phase vertical distribution properties. The multiple scattering code generates an internal layer for each layer of precipitation in the input atmosphere. The original Jin and Isaacs (1987) algorithm which treated a two layer rain model (i.e. ice layer over rain layer or two rain layers with differing rain rates) was extensively modified to provide a generalized "n" layer calculation. No attempt was made to reduce this number of layers through layer merging procedures. This could potentially reduce computer time for the multiple scattering option.

The multiple scattering option runs interactively with the surface modeling capability. The appropriate surface emissivity as a function of angle is utilized to provide lower boundary conditions to the multiple scattering calculation which takes into account the surface emission, upward atmospheric emission, and reflection of downward atmospheric emission incident at the lower boundary of the precipitation. This boundary condition is satisfied for each Gauss point of the discrete ordinate calculation.

4.5 Retrieval Algorithm

We have included a generalized statistical parameter inversion method for use with RADTRAN. The statistical retrieval approach is described in Isaacs and Deblonde (1987), Isaacs et al. (1988), and Isaacs (1987,1988) applied to the remote sensing of surface temperature and emissivity, temperature profile, and water vapor profile. Jin and Isaacs (1987) also applied the approach to the inference of rain rate using simulated scattered brightness temperatures. Isaacs (1989) uses the statistical retrieval as a first guess for the unified retrieval approach for DMSP meteorological sensors.

The r trieval algorithm is not integrated with the RADTRAN code, rather it functions as a separate entity. In application, the relationship between the statistical retrieval algorithm and RADTRAN is a simple one. RADTRAN is used as the forward problem calculation to generate synthetic data from an ensemble of model atmospheres or a radiosonde data set for a desired sensor system. The statistical retrieval algorithm reads in these simulated data to calculate the required statistical regression coefficients for the retrieval from one set of simulated data and to test the accuracy of the retrieval using the regression statistics from a second independent set of simulated data. The procedure is described in the above cited references.

5. DOCUMENTATION AND USERS GUIDE

5.1 Description of Enhanced RADTRAN

The original RADTRAN algorithm consisted of four integrated modules:

a) atmospheric models (including rain)
b) attenuation calculation
c) calculation of weighting functions
d) brightness temperature calculation

All four of the above functions were performed in the main body of the original RADTRAN (formerly named SKYTMP). In order to improve the readability of the code three new subroutines were created to isolate computational elements from the main program which was converted into an executive calling routine. The new subroutines are (see Figure 2):

a) ATMPRF which sets up and prints out the desired atmospheric profile. ATMPRF also alternatively calls INPROF to read in a user-supplied profile.

b) ATTEN which performs the attenuation calculation and also calculates weighting functions if desired.

c) RDTRAN which calculates the brightness temperatures including the contribution from the surface if desired.

The rotational lines for water are now in data statements and don't require inputting unless the user desires a new set.

The input parameters themselves were slightly modified, as can be seen from the user instructions (see Section 5.2). The major changes however are in the three new features that have been added. These are: a) precipitation models which provide the absorption and extinction coefficients for the desired rain rate, frequency, and temperature; b) surface models which provide the surface emissivity for a variety of surfaces including ocean, snow, sea ice, soil, and vegetation; and c) a multiple scattering routine has been added so that the scattering effects of precipitating layers in the atmosphere can be modeled.

The implementation of the precipitation model was accomplished by the addition of three (3) new routines: a) SCAT, b) BS, and c) TAB. SCAT is the driver for the precipitation model and uses BS, a binary search routine, and absorption and extinction coefficients for the desired inputs. The model outputs are printed to the main output file RADOUT, but are not used directly by RADTRAN.

The surface models (see Figure 3) on the other hand can be used to directly feed the required emissivities for the desired look angles into the brightness temperature calculation. The main driver SRFMOD is used to read in the necessary inputs, calls DWATER and DSOIL to provide the necessary dielectric constants, calls EMIS to produce the emissivities at the gauss points, and then calls AITINT to interpolate the emissivities to the desired angles. EMIS is the primary routine in which the code decides based on user input how to calculate the emissivities. For calm ocean the program utilizes a model of a dielectric slab, for rough ocean, sea ice, or snow, a model of random discrete scatterers is used, and for vegetation or soil, a continuous random medium model is used.

The multiple scattering routine (see Figure 4) provides another alternative to the standard RADTRAN run. It allows the user to fully model the effects that precipitating layers have on the observed radiance. The driver routine MLTSCT sets up the layers containing precipitation for the model, and calculates the boundary conditions using the routine RDTNMS. The polarized multiple scattered radiance is then calculated in MSPTRT. This radiance which is calculated at the six (6) Gauss points is then interpolated by AITINT.

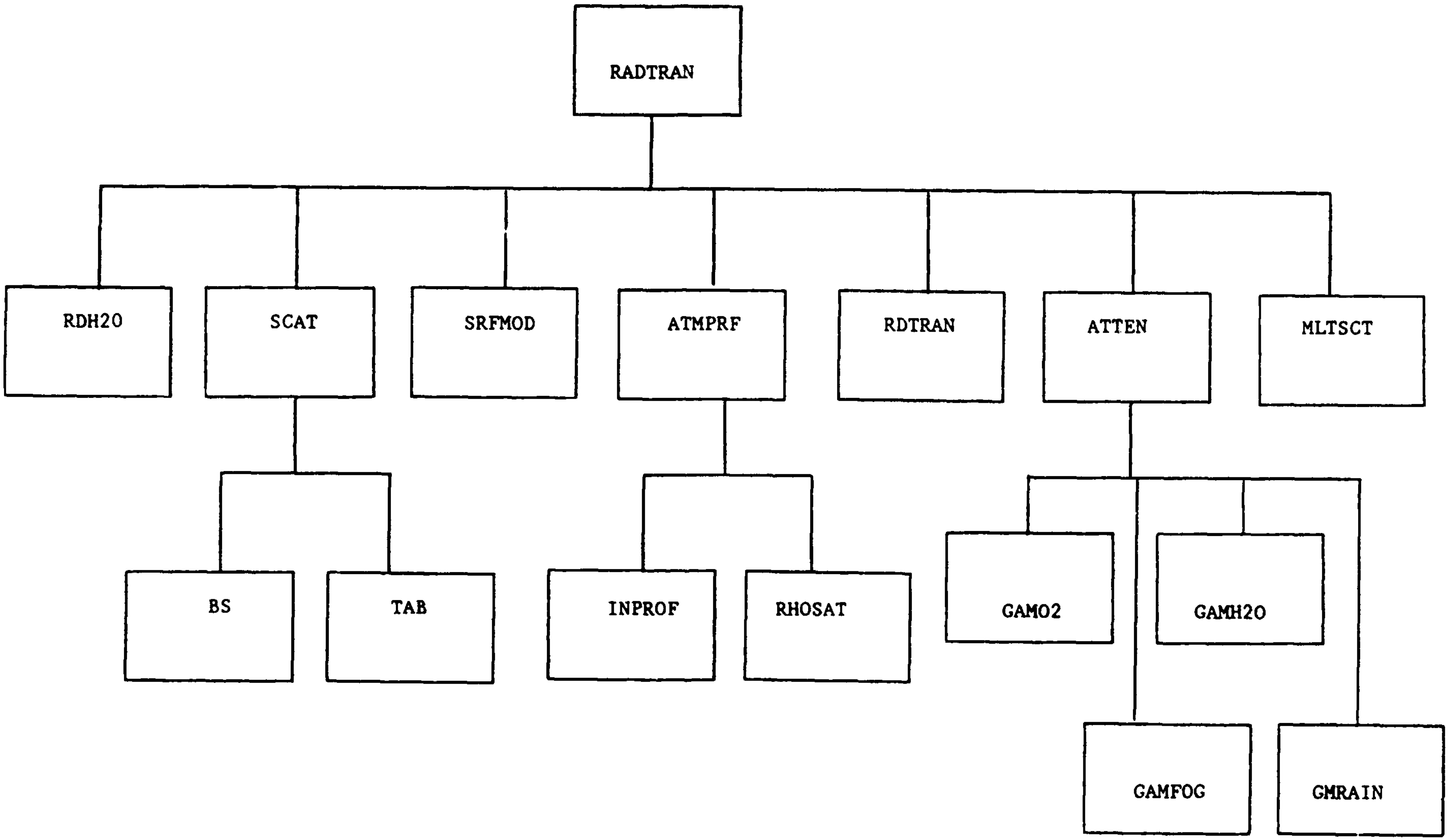

Figure 2. Enhanced RADTRAN flowchart.

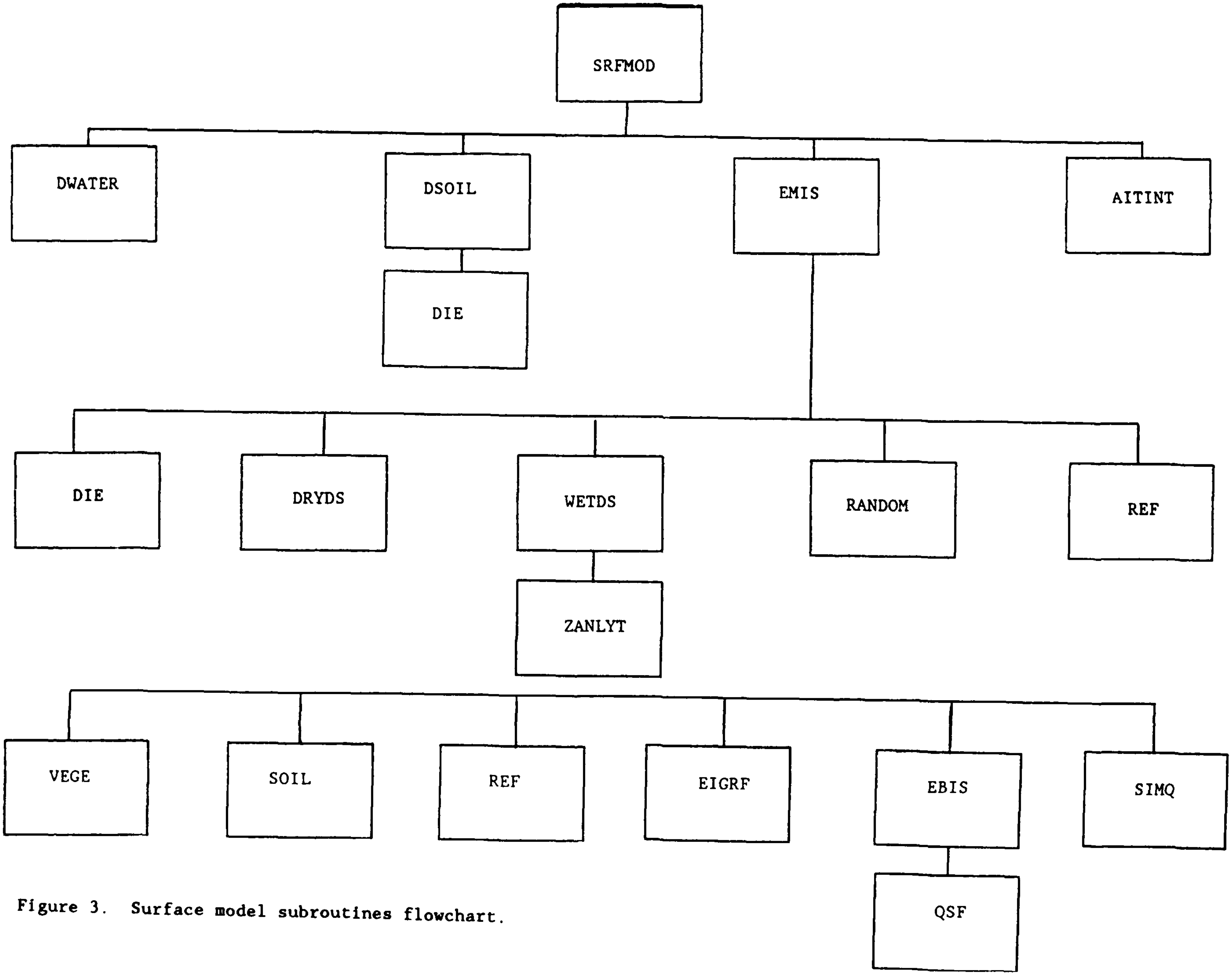

Figure 3. Surface model subroutines flowchart.

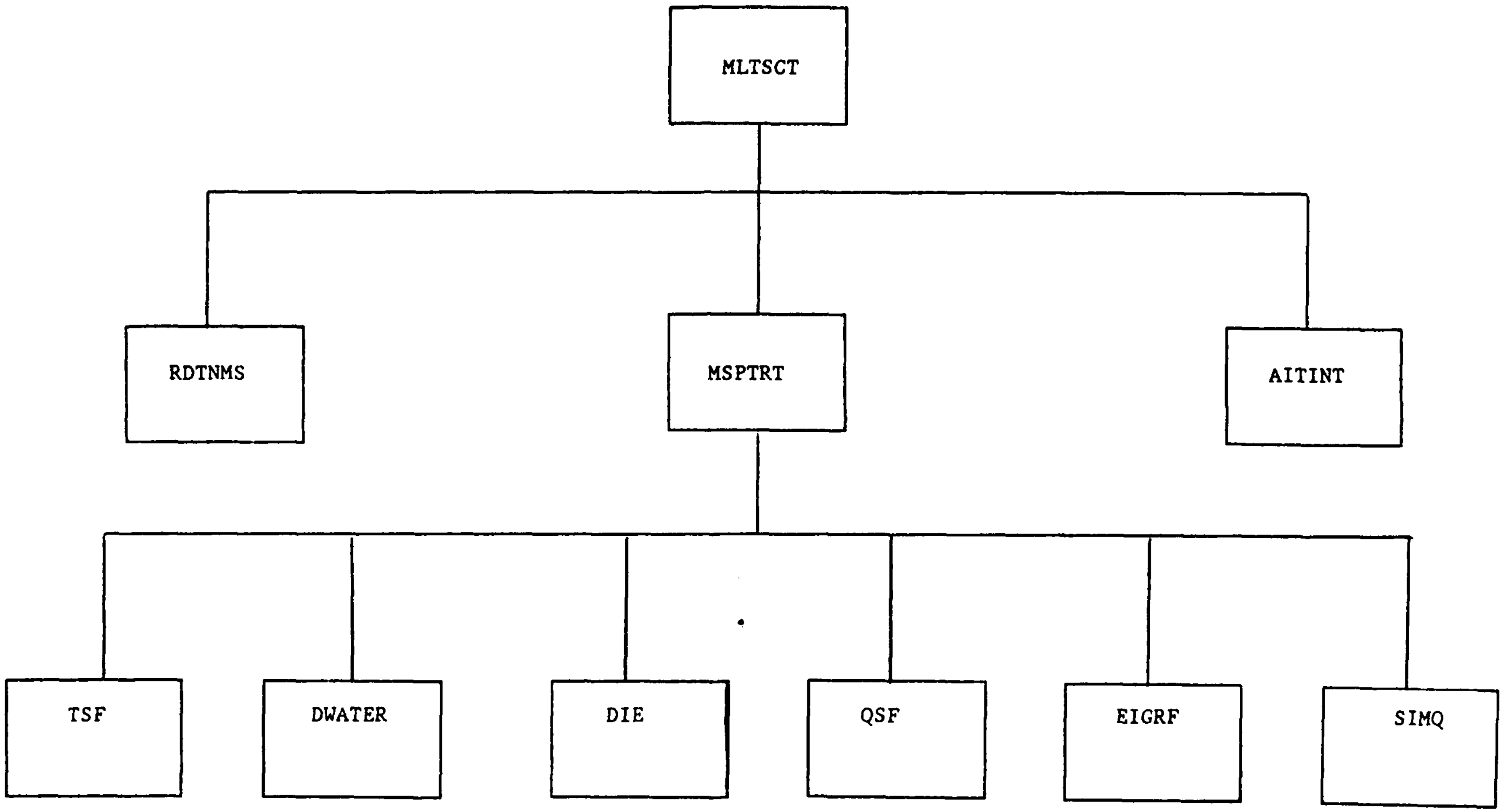

Figure 4. Multiple scattering model subroutines flowchart.

The program structure and subroutine hierarchy of enhanced RADTRAN is outlined in Table 3, which also provides brief descriptions of all subroutines and functions. What is not obvious however, is the scope of the changes that have been made. RADTRAN as it previously existed has approximately 1500 lines of code. The new enhanced RADTRAN is approximately 7500 lines of code. Unfortunately along with the increase in size of the code came an increase in the storage required. Currently the code will run unsegmented on AFGL's CYBER 180-860, it does however use approximately 300K of extended core.

Table 3. Subroutine Hierarchical Structure for the Enhanced RADTRAN

```
PROGRAM RADTRAN                      Main Program
| SUBROUTINE SCAT                    Driver for Precipitation Model
| | SUBROUTINE BS                    Binary Search Routine
| | FUNCTION TAB                     Table of Absorption and
| | |                                   Extinction Coefficients
| SUBROUTINE ATMPRF                  Sets up the Atmospheric Profile
| | SUBROUTINE INPROF                Reads in User Supplied Profile
| | FUNCTION RHOSAT                  Computes Water Vapor Density
| SUBROUTINE SRFMOD                  Driver for Surface Models
| | SUBROUTINE DWATER                Dielectric Constant for Water
| | SUBROUTINE DSOIL                 Dielectric Constant for Soil
| | | SUBROUTINE DIE                 Water and Ice Dielectric Permittivities
| | SUBROUTINE EMIS                  Driver for Emissivity Calculation
| | | SUBROUTINE DIE                 Water and Ice Dielectric Permittivities
| | | SUBROUTINE DRYDS               Calculate Emissivities for a Dry
| | | |                               Random Discrete Scattering Medium
| | | SUBROUTINE WETDS               Calculate Emissivities for a Wet
| | | |                               Random Discrete Scattering Medium
| | | | SUBROUTINE ZANLYT            IMSL - Zeroes of an Analytic
| | | | |                                   Complex Function
| | | | | SUBROUTINE UERTST          IMSL - Prints Error Condition
| | | | | | SUBROUTINE USPKD         IMSL - Required by UERTST
| | | | | | SUBROUTINE UGETIO        IMSL - Obtains I/O Units
| | | | FUNCTION CFUN                Algebraic Function
| | | | |                               X^3+C1*X^2+C2*X+C3
| | | SUBROUTINE RANDOM              Calculate Emissivities for
| | | |                               Continuous Random Medium
| | | | SUBROUTINE VEGE              Mean Dielectric Constant and
| | | | |                             Variance for Vegetation
| | | | SUBROUTINE SOIL              Mean Dielectric Constant and
| | | | |                             Variance for Soil
| | | | SUBROUTINE REF               Calculates the Reflectivities
| | | | SUBROUTINE EBIS              Compute Scattering Phase Functions
| | | | | SUBROUTINE QSF             Compute Vector of Integral Values
```

Table 3. Subroutine Hierarchical Structure for the Enhanced RADTRAN (continued)

```
| | | | SUBROUTINE EIGRF          IMSL - Eigenvalues and Eigenvectors
| | | | |                                of a Real General Matrix
| | | | | SUBROUTINE EBALAF       IMSL - Required by EIGRF
| | | | | SUBROUTINE EHESSF       IMSL - Required by EIGRF
| | | | | SUBROUTINE EHBCKF       IMSL - Required by EIGRF
| | | | | SUBROUTINE EQRH3F       IMSL - Required by EIGRF
| | | | | | SUBROUTINE UERTST     IMSL - Prints Error Condition
| | | | | | | SUBROUTINE USPKD    IMSL - Required by UERTST
| | | | | | | SUBROUTINE UGETIO   IMSL - Obtains I/O Units
| | | | | SUBROUTINE EBBCKF       IMSL - Required by EIGRF
| | | | | SUBROUTINE UERTST       IMSL - Prints Error Condition
| | | | | | SUBROUTINE USPKD      IMSL - Required by UERTST
| | | | | | SUBROUTINE UGETIO     IMSL - Obtains I/O Units
| | | | SUBROUTINE SIMQ           Solve Matrix AX=B
| | | SUBROUTINE REF              Calculates the Reflectivities
| | SUBROUTINE AITINT             Aitken's Iterated Interpolation
| SUBROUTINE RDH2O                Reads in H2O Rotational Lines
| SUBROUTINE PLTID3               AFGL Plot Header Routine
| SUBROUTINE PLOT                 Various Plot Functions
| SUBROUTINE ATTEN                Compute Atmospheric Attenuation
| | FUNCTION GAMO2                Compute Oxygen Attenuation
| | FUNCTION GAMH2O               Driver for Computing Water Attenuation
| | | SUBROUTINE ALPHAG           Computes Water Attenuation (>300 GHZ)
| | | SUBROUTINE ALPHA5           Computes Water Attenuation (5<f<300 GHZ)
| | FUNCTION GAMFOG               Computes Attenuation for Condensed Water
| | |                                in Cloud or Fog
| | | SUBROUTINE DPH2O            Computes Dielectric Properties of Water
| | | SUBROUTINE INDEX            Computes Refractive Index
| | | | SUBROUTINE DEBYE          Required by INDEX
| | | | FUNCTION DOP              Required by INDEX
| | | | FUNCTION AB               Required by INDEX
| | FUNCTION GMRAIN               Computes Attenuation for Condensed Water
| | |                                in form of Rain
| | |   FUNCTION AITK             Required by GMRAIN
| SUBROUTINE MLTSCT               Driver for Multiple Scattering Routine
| | SUBROUTINE RDTNMS             Computes Boundary Conditions and
| | |                                Contributions from non-scattering layer
| | SUBROUTINE MSPTRT             Multiple Scattering Routine
| | | SUBROUTINE TSF              Computes TNM and SNM Functions
| | | SUBROUTINE DWATER           Dielectric Constant for Water
| | | SUBROUTINE DIE              Water and Ice Dielectric Permittivities
| | | SUBROUTINE QSF              Compute Vector of Integral Values
| | | SUBROUTINE EIGRF            IMSL - Eigenvalues and Eigenvectors
| | | |                                  of a Real General Matrix
| | | | SUBROUTINE EBALAF         IMSL - Required by EIGRF
| | | | SUBROUTINE EHESSF         IMSL - Required by EIGRF
| | | | SUBROUTINE EHBCKF         IMSL - Required by EIGRF
| | | | SUBROUTINE EQRH3F         IMSL - Required by EIGRF
```

Table 3. Subroutine Hierarchical Structure for the Enhanced RADTRAN (continued)

```
| | | | | SUBROUTINE UERTST        IMSL - Prints Error Condition
| | | | | | SUBROUTINE USPKD      IMSL - Required by UERTST
| | | | | | SUBROUTINE UGETIO     IMSL - Obtains I/O Units
| | | | SUBROUTINE EBBCKF          IMSL - Required by EIGRF
| | | | SUBROUTINE UERTST          IMSL - Prints Error Condition
| | | | | SUBROUTINE USPKD         IMSL - Required by UERTST
| | | | | SUBROUTINE UGETIO        IMSL - Obtains I/O Units
| | | SUBROUTINE SIMQ              Solve Matrix AX=B
| | SUBROUTINE AITINT              Aitken's Iterated Interpolation
| SUBROUTINE RDTRAN                Computes Brightness Temperature
| |                                   for the non-Multiple Scattering Cases
| SUBROUTINE DRAW                  Driver for Plotting Routines
| | SUBROUTINE AXIS                Draws Axis
| | SUBROUTINE NUMBER              Draws Number
| | SUBROUTINE LINE                Draws a Line
| | SUBROUTINE SYMB                Sets up call to SYMBOL
| | | SUBROUTINE SYMBOL            Draws a Symbol
| | SUBROUTINE WHERE               Returns Pen Location
| | SUBROUTINE PLOT                Various Plot Functions
| | SUBROUTINE FRAME               Draws Frame
| | SUBROUTINE ENDPLT              AFGL Plot Terminating Routine
```

5.2 Enhanced RADTRAN User Instructions

Although the enhanced RADTRAN code now contained some sophisticated options every attempt was made to keep the user interface as simple as possible. This meant continuity with the old RADTRAN input format and the introduction of LOWTRAN type input and file assignments. Table 4 lists the file assignments for RADTRAN. Table 5 summarizes the input instructions for enhanced RADTRAN as they are included in the code itself.

Table 4. File Assignments for RADTRAN

TAPE5	RADTRAN INPUT FILE (SKYPAR)
TAPE6	RADTRAN OUTPUT FILE (RADOUT)
TAPE7	TABULAR RADIANCE OUTPUT FILE (RADTAB)
TAPE8	SURFACE MODEL OUTPUT FILE (EMIDAT)
TAPE9	BINARY OUTPUT FILE - USED TO STORE WEIGHTING FUNCTIONS (RADPLT)
TAPE10	SPECTRAL RANGE OF FREQUENCIES (RADSPC)
TAPE20	WATER VAPOR SPECTRAL LWE PARAMETER INPUT FILE (H2OROT)
TAPE39	AFGL PLOT FILE

Table 5. Input Instructions for RADTRAN

```
CARD 1:  TITLE
  FORMAT (A80)

  TITLE IS USED AS A HEADER RECORD FOR OUTPUT PURPOSES

--------------------------------------------------------------------

CARD 2: IRDTRN,IATM,ISRFC,IMS,IPLOT,NANGLE,MODE,ITABLE,
               IATTEN,IATINC,IWF,IWFINC,IRDH2O,NOPR,TGRND
  FORMAT (14(3X,I2),F10.5)

  IRDTRN= 0  PROFILE AND SURFACE MODELS SET UP (RADTRAN NOT RUN)
        = 1  FOR RADTRAN RUN
        = 2  FOR RUN OF PRECIPITATION MODEL (RADTRAN NOT RUN)

  IATM  = 0  FOR USER SUPPLIED ATMOSPHERE
        = 1  FOR STANDARD MODEL

  ISRFC = 0  NO SURFACE USED IN CALCULATION
        = 1  INTERNAL MODEL SUPPLIES SURFACE TEMPERATURE
                AND EMISSIVITY
             (NOTE:  FOR MODELS 1-4, FREQ MUST BE LESS THAN 35 GHZ)
        = 2  USER SUPPLIED SURFACE TEMPERATURE, INTERNAL
                MODEL PROVIDES EMISSIVITY
        = 3  USER SUPPLIED SURFACE TEMPERATURE AND
                EMISSIVITY

  IMS   = 0  NO MULTIPLE SCATTERING
        = 1  MULTIPLE SCATTERING RUN

  IPLOT = 0  NO PLOTTING
        = 1  PLOT

  NANGLE IS THE NUMBER OF ANGLES TO BE INPUTED (MAX=10)

  MODE DETERMINES HOW FREQUENCIES ARE INPUTED
        = 0  READ IN BEGINNING AND ENDING FREQUENCY AND INCREMENT
        = 1  READ IN INDIVIDUAL FREQUENCIES

  ITABLE DETERMINES IF TABULAR OUTPUT IS WRITTED TO RADTAB
        = 0 FOR NO TABLE PRINTED
        = 1 FOR TABLE PRINTED TO RADTAB

  IATTEN DETERMINES IF ATTENUATIONS ARE PRINTED
        = 0 FOR NO ATTENUATION PRINTED
        = 1 FOR ATTENUATION PRINTED

  IATINC IS THE INCREMENT FOR WHICH ATTENUATIONS ARE PRINTED
        = 1 EVERY ATTENUATION PRINTED
        = N FOR EVERY NTH ATTENUATION PRINTED
```

IWF DETERMINES IF WEIGHTING FUNCTIONS ARE PRINTED
- = 0 FOR NO WEIGHTING FUNCTIONS PRINTED
- = 1 FOR WEIGHTING FUNCTIONS PRINTED

IWFINC IS THE INCREMENT FOR WHICH WEIGHTING FUNCTIONS ARE PRINTED
- = 1 EVERY WEIGHTING FUNCTION PRINTED
- = N FOR EVERY NTH WEIGHTING FUNCTION PRINTED

IRDH2O IS THE FLAG FOR USER INPUTED WATER-VAPOR ROTATION SPECTRAL LINE PARAMETERS
- = 0 USES INTERNAL LINES
- = 1 READS IN LINES FROM FILE H2OROT

NOPR IS THE FLAG TO RESTRICT THE SIZE OF THE PRINTOUT
- = 0 FULL PRINTOUT
- = 1 LIMITED PRINTOUT

TGRND IS THE SURFACE TEMPERATURE (ISRFC=2,3)
(SET TO T(1) FOR TGRND=0.0)

CARD 3: DIST,PHASE,FREQ,RNRATE,TEMP (IRDTRN=2)
FORMAT (3F10.3,2I5)

DIST DETERMINES THE DROP SIZE DISTRIBUTION
- = 1 FOR MARSHALL-PALMER
- = 2 FOR BEST
- = -1 WILL TERMINATE PRECIPITATION MODEL RUN

PHASE DETERMINES THE PHASE OF THE PRECIPITATION
- = 1 FOR WATER
- = 2 FOR ICE

FREQ IS THE FREQUENCY IN GHZ (19.35 - 231.0 GHZ)

RNRATE IS THE RAINFALL RATE IN MM/HR (0.0 - 50.0 MM/HR)

TEMP IS THE TEMPERATURE IN DEGREES K (263.0 - 283.0 K)

**** REPEAT CARD 3 ****

CARD 4.1.1: ICNTRL,M,ATITLE (IATM=0)
FORMAT (2(3X,I2),A70)

```
ICNTRL DETERMINES HOW PROFILE IS TO BE INPUTED
      = 0  READ IN PROFILE IN TABULAR FORM
      = 1  READ IN PROFILE IN COMPACT FORM
      = 2  READ IN PROFILE IN COMPACT FORM  (NO RAIN)
      = 3  READ IN PROFILE IN COMPACT FORM  (NO CLOUDS, NO RAIN)

M IS THE NUMBER OF LEVELS TO BE READ IN

ATITLE IS A HEADER TO IDENTIFY THE PROFILE INPUTED
```

```
CARD 4.1.2: FMT  (ICNTRL=0,1)
  FORMAT (A80)

  FMT IS THE FORMAT TO BE USED FOR INPUTING THE PROFILE
```

```
CARD 4.1.3: H,P,T,RH,CLOUD,RAIN  (ICNTRL=0)
  FORMAT (INPUT FROM CARD 4.1.2)

  H IS THE HEIGHT IN KM

  P IS THE PRESSURE IN MB

  T IS THE HEIGHT IN KM

  RH IS THE RELATIVE HUMIDITY

  CLOUD IS THE CLOUD AMOUNT

  RAIN IS THE RAIN RATE (MM/HR)
```

```
CARD 4.2: MOD,MHUMID,MCLOUD,MRAIN  (IATM=1)
  FORMAT (4(3X,I2))

  MOD    = 1  TROPICAL MODEL
         = 2  MID-LATITUDE SUMMER MODEL
         = 3  MID-LATITUDE WINTER MODEL
         = 4  SUB-ARCTIC SUMMER MODEL
         = 5  SUB-ARCTIC WINTER MODEL
         = 6  U.S. STANDARD (1962) MODEL

  MHUMID= 1  TROPICAL MODEL
         = 2  MID-LATITUDE SUMMER MODEL
         = 3  MID-LATITUDE WINTER MODEL
         = 4  SUB-ARCTIC SUMMER MODEL
```

```
         = 5  SUB-ARCTIC WINTER MODEL
         = 6  U.S. STANDARD (1962) MODEL
         = 7  TYPICAL HUMIDITIES IN RAINY ATMOSPHERE
         = 8  TYPICAL HUMIDITIES IN CLOUD ONLY ATMOSPHERE

   MCLOUD= 1  NO CLOUDS
         = 2  STRATUS/STRATO CUMULUS  0.15 G/M3  0.5-2.0 KM
         = 3  CUMULUS 1.0 G/M3  1.0-3.5 KM
         = 4  ALTO STRATUS  0.4 G/M3  2.5-3.0 KM
         = 5  STRATUS CUMULUS  0.55 G/M3  0.5-1.5KM
         = 6  NIMBOSTRATUS  0.61 G/M3  0.5-1.0KM

   MRAIN = 1  NO RAIN
         = 2  DRIZZLE 2MM/HR AT SFC
         = 3  LIGHT RAIN 5MM/HR AT SFC
         = 4  STEADY RAIN 12.5MM/HR AT SFC
         = 5  SUMMER CUMULUS RAIN 15.0 MM/HR AT SFC
         = 6  HEAVY RAIN 20MM/HR AT SFC
```

```
 CARD 5.1.1: IGRND,IEMTAB,TEMP1,TEMP2   (ISRFC=1,2)
   FORMAT (3X,I2,2F10.5)

   IGRND IS THE SURFACE MODEL DESIRED

   IEMTAB IS THE FLAG TO PRINT A TABLE OF EMISSIVITES
            TO THE FILE EMIDAT
         = 0 NO TABLE PRINTED
         = 1 EMISSIVITY TABLE PRINTED

   TEMP1 IS THE TEMPERATURE OF THE UPPER SURFACE LAYER
            (SET TO TGRND FOR TEMP1 = 0.0)

   TEMP2 IS THE TEMPERATURE OF THE LOWER SURFACE LAYER
            (SET TO TGRND FOR TEMP2 = 0.0)
```

```
 CARD 5.1.2: A,FRAC,EB,E2DRY,DEPDRY  (IGRND=1,2,3)
   FORMAT (7F10.6)
    ** ROUGH OCEAN, SEA ICE, OR DRY SNOWPACK **

   A IS THE SCATTERER SIZE

   FRAC IS THE FRACTION VOLUME

   EB IS THE LAYER PERMITTIVITY
```

E2DRY IS THE PERMITTIVITY FOR THE SURFACE

DEPDRY IS THE DEPTH OF THE LAYER

CARD 5.1.3: A1,FS1,A2,FS2,E2WET,DEPWET (IGRND=4)
FORMAT (7F10.6)
** WET SNOWPACK **

A1 IS THE SCATTERER SIZE FOR THE UPPER LAYER

FS1 IS THE TOTAL FRACTION FOR THE UPPER LAYER

A2 IS THE SCATTERER SIZE FOR THE LOWER LAYER

FS2 IS THE TOTAL FRACTION FOR THE LOWER LAYER

E2WET IS THE PERMITTIVITY FOR LOWER LAYER

DEPWET IS THE DEPTH OF THE LAYER

CARD 5.1.4: LP,LZ,MV,E2RAN,DEPRAN,H,DMV (IGRND=5,6,7)
FORMAT (8F10.6)
** VEGETATION, WET SOIL, AND RANDOM MEDIUM **

LP IS THE CORRELATION LENGTH

LZ IS CORRELATION OF Z-EXPONATIOAL

MV IS VOLUMETRIC MOISTURE IN VEGETATION

E2RAN IS THE DIELECTRIC CONSTANT

DEPRAN IS THE DEPTH OF THE LAYER

H IS THE ROUGHNESS

DMV IS THE VOLUMETRIC MOISTURE USED IN CALCULATING E2RAN

CARD 5.1.5: VV,VB,VBW,BULK (IGRND=5)
FORMAT (5F10.6)
** VEGETATION **

VV IS THE VEGETATION FRACTION IN LAYER

```
    VB IS THE DRY VEGETATION IN VEGETATION

    VBW IS THE BOUNDED WATER FRACTION IN MV

    BULK DIELECTRIC CONSTANT
---------------------------------------------------------------------

  CARD 5.1.6: WT,GA,PO,ROCK   (IGRND=6)
    FORMAT (5F10.6)
     ** WET SOIL **

    WT IS THE TRANSION WETNESS

    GA IS THE MIXING PARAMETER

    PO IS THE POROCITY

    ROCK IS THE ROCK PERMITTIVITY

---------------------------------------------------------------------

  CARD 5.1.7: EM,DEL  (IGRND=7)
    FORMAT (3F10.6)
     ** RANDOM MEDIUM **

    EM IS THE AVERAGE DIELECTRIC CONSTANT OF THE RANDOM MEDIUM

    DEL IS THE VARIANCE

        ** NOTE : THESE ARE FREQUENCY DEPENDENT, SO FOR MODE=1
                  MUST ALSO READ IN ON CARD 9.2

---------------------------------------------------------------------

  CARD 5.2: EMISH(1),EMISH(2),...,EMISH(10)  (ISRFC=3)
    FORMAT (10F8.4)

    EMISH(I) IS THE HORIZONTAL EMISSIVITY CORRESPONDING
          TO ANGLE(I)

---------------------------------------------------------------------

  CARD 5.3: EMISV(1),EMISV(2),...,EMISV(10)  (ISRFC=3)
    FORMAT (10F8.4)

    EMISV(I) IS THE VERTICAL EMISSIVITY CORRESPONDING
          TO ANGLE(I)
---------------------------------------------------------------------
```

Table 5. Input Instructions for RADTRAN (continued)

```
CARD 6.1: EMHMS  (IMS=1 AND ISFRC=3)
  FORMAT (6F10.6)

  EMHMS IS THE HORIZONTAL EMISSIVITY CORRESPONDING TO EACH OF
        THE SIX GAUSS POINTS USED BY MULTIPLE SCATTERING

  GAUSS ANGLES ARE 11.02, 25.30, 39.65, 54.03, 68.42, & 82.81

----------------------------------------------------------------------

CARD 6.2: EMVMS  (IMS=1 AND ISFRC=3)
  FORMAT (6F10.6)

  EMVMS IS THE VERTICAL EMISSIVITY CORRESPONDING TO EACH OF
        THE SIX GAUSS POINTS USED BY MULTIPLE SCATTERING

  GAUSS ANGLES ARE 11.02, 25.30, 39.65, 54.03, 68.42, & 82.81

----------------------------------------------------------------------

CARD 7: NAME  (IPLOT=1)
  FORMAT (A30)

  NAME IS THE CHARACTER RECORD USED TO IDENTIFY PLOTS

----------------------------------------------------------------------

CARD 8: ANGLE(1),ANGLE(2),....,ANGLE(10)
  FORMAT (10F8.4)

  ANGLE(I) IS THE LOOK ANGLE (IN DEGREES)

----------------------------------------------------------------------

CARD 9.1: V1,V2,DV  (ONLY FOR MODE=0)
  FORMAT (3F10.5)

  V1 IS THE BEGINNING FREQUENCY

  V2 IS THE ENDING FREQUENCY

  DV IS THE FREQUENCY INCREMENT

----------------------------------------------------------------------

CARD 9.2: V1,V2,V3,E2,DELF  (ONLY FOR MODE=1)
  FORMAT (6F10.5)

  V1 IS THE CENTER FREQUENCY
```

Table 5. Input Instructions for RADTRAN (continued)

```
    V2 IS THE FIRST SIDEBAND

    V3 IS THE SECOND SIDEBAND

    E2 IS THE PERMITTIVITY  (ISRFC=1,2  AND  IGRND=1,5,6)
         (PROGRAM WILL CALCULATE FOR E2=(0.,0.))

    E2 IS (EM) THE AVERAGE DIELECTRIC CONSTANT FOR THE
         RANDOM MEDIUM  (ISFRC=1,2  AND  IGRND=7)

    DELF IS THE VARIANCE FOR EM  (IGRND=7)

----------------------------------------------------------------------

  CARD 10: IRPT
    FORMAT (3X,I2)

    IRPT DETERMINES NEXT PROGRAM OPERATION

         = 0  PROGRAM TERMINATES

         = 1  PROGRAM RERUN READING ALL INPUT CARDS

         = 2  PROGRAM RERUN READING IN NEW HEADER AND
                 OTHER INPUTS STARTING WITH ATMOSPHERE

         = 3  PROGRAM RERUN READING IN NEW HEADER AND
                 OTHER INPUTS STARTING WITH SURFACE TERMS
```

5.3 Enhanced RADTRAN Test Cases

In order to demonstrate some of the new features of the RADTRAN program, we have generated four different test cases. In test case 1 we have exercised the precipitation model. The precipitation model option (IRDTRN=2) on CARD 2, allows the user to obtain the absorption and extinction coefficients along with the first eight legendre coefficients as outlined in the user instructions (see CARD 3 in Table 5). In the input file for test case 1 (see Table 6) we have chosen three frequencies (19.35, 37.00, and 85.50 GHZ), four rainrates (25.0, 10.0, 5.0, and 1.0 MM/HR), and two temperatures (270.0 and 280.0 K). The output (see Table 7) shows the desired quantities for each of the input parameters selected.

For the second test case, the surface model option is exercised. The internal surface model option (ISRFC=1,2) on CARD 2, allows the user to tailor the surface parameters used by RADTRAN to reflect several different physical ground conditions. In the input file for test case 2 (see Table 8), we have chosen four different surfaces to evaluate. These are a) CALM OCEAN, b) WET SNOWPACK, c) VEGETATION, and d) WET SOIL. Although we allowed most of the model parameters to use the defaults, a large number of possible permutations exist for the user to chose from (see CARDS 5.1.1 - 5.1.7 in Table 5). This test case produces three output files. The main RADTRAN output (see Table 9) is placed on file RADOUT.

In the first section of this output file is printed the atmospheric profile used. In this case, a tropical model was chosen. Following the atmospheric profile is a listing of the water-vapor rotational spectral line parameters. These are stored internally, but can be inputted by the user if desired. The next section shows the attenuations at every level. This table is optionally printed by changing the IATTEN flag on CARD 2. Following the attenuations is a table of weighting functions for both ground-to-space and space-to-ground. The weighting functions can also be optionally chosen by changing the IWF flag on CARD 2. Following the weighting functions is the result for the first frequency (10.6 GHZ). This provides the brightness temperature looking up, and the polarized brightness temperature looking down. Also provided is the polarized emissivities used by the routine. In this case, the emissivities printed are those obtained from the surface model. The next table contains the attenuations for the second frequency

(18.0 GHZ), followed by its weighting functions and the brightness temperature results.

The next section begins the RADTRAN run for the WET SNOW case. The user should note that CARD 10, allows the repeated runs of RADTRAN from one input file. The rest of the output file contains the attenuations and brightness temperature for the VEGETATION and WET SOIL runs.

When running the surface models, a more extensive output is usually desired. This can be obtained by setting IEMTAB=1 on CARD 5.1.1. This will produce the additional output file EMIDAT (see Table 10). This output file shows the inputs used by the surface models whether user selected or defaults, along with the calculated emissivities. An additional output which can be selected (ITABLE=1 on CARD 2) is printed on file RADTAB (see Table 11). This option provides a concise tabulated output file in addition to the main output.

For the third test case, the multiple scattering option is exercised. This option is chosen by selecting IMS=1 on CARD 2. For this test case (see Table 12) we have chosen a moist vegetation surface and a tropical model. In addition we have chosen two different rainrates, a light rain, and a summer cumulus rain. Both multiple scattered and no multiple scattered results are desired. The only difference of note in the output files, is that for multiple scattered cases, no upward brightness temperatures are currently calculated. The main output for the test case 3 run is provided in Table 13. The surface model output (Table 14) and the tabulated output (Table 15) are also provided. As can be seen from the output, there is a significant difference between the calculated brightness temperatures from the multiple scattered cases and the non multiple scattered cases.

The final test case demonstrates the MODE=0 option on CARD 2. This option allows the user to select a starting and ending frequency along with an increment to obtain the output over a spectral range of frequencies. For this case (see Table 16) we chose the interval 182.0-184.0 GHZ, incrementing every 0.1 GHZ. For computational efficiency the emissivities were set to 1.0. The main output file, RADOUT (see Table 17), can be quite large especially if the attenuations and weighting functions are desired. For this case we did not turn on those print options. In this case, the advantages of the RADTAB output file (see Table 18) are readily apparent. If the user does desire the

total attenuations for each frequency, the IATTEN=1 flag produces an additional output file, RADSPC (see Table 19). This provides a concise tabulated file of total attenuations at every frequency. Note, however, RADOUT will be significantly larger with IATTEN=1.

An additional note about cpu usage. Each of these test cases was run on AFGL's CYBER 180-860 and the run time recorded. For case 1, it took .273 seconds; for case 2, 106.524 seconds; for case 3, 576.093 second; and for case 4, 4.835 seconds.

Table 6. Input for Precipitation Model Test Case 1

```
 TEST CASE 1 - PRECIPITATION MODEL
RAD 2
DST 1 PH 1   19.35   25.0      280.0
DST 1 PH 1   19.35   10.0      280.0
DST 1 PH 1   19.35    5.0      280.0
DST 1 PH 1   19.35    1.0      280.0
DST 1 PH 1   19.35   25.0      270.0
DST 1 PH 1   19.35   10.0      270.0
DST 1 PH 1   19.35    5.0      270.0
DST 1 PH 1   19.35    1.0      270.0
DST 2 PH 1   19.35   25.0      280.0
DST 2 PH 1   19.35   10.0      280.0
DST 2 PH 1   19.35    5.0      280.0
DST 2 PH 1   19.35    1.0      280.0
DST 2 PH 1   19.35   25.0      270.0
DST 2 PH 1   19.35   10.0      270.0
DST 2 PH 1   19.35    5.0      270.0
DST 2 PH 1   19.35    1.0      270.0
DST 1 PH 1   37.00   25.0      280.0
DST 1 PH 1   37.00   10.0      280.0
DST 1 PH 1   37.00    5.0      280.0
DST 1 PH 1   37.00    1.0      280.0
DST 1 PH 1   37.00   25.0      270.0
DST 1 PH 1   37.00   10.0      270.0
DST 1 PH 1   37.00    5.0      270.0
DST 1 PH 1   37.00    1.0      270.0
DST 2 PH 1   37.00   25.0      280.0
DST 2 PH 1   37.00   10.0      280.0
DST 2 PH 1   37.00    5.0      280.0
DST 2 PH 1   37.00    1.0      280.0
DST 2 PH 1   37.00   25.0      270.0
DST 2 PH 1   37.00   10.0      270.0
DST 2 PH 1   37.00    5.0      270.0
DST 2 PH 1   37.00    1.0      270.0
DST 1 PH 1   85.50   25.0      280.0
DST 1 PH 1   85.50   10.0      280.0
DST 1 PH 1   85.50    5.0      280.0
DST 1 PH 1   85.50    1.0      280.0
DST 1 PH 1   85.50   25.0      270.0
DST 1 PH 1   85.50   10.0      270.0
DST 1 PH 1   85.50    5.0      270.0
DST 1 PH 1   85.50    1.0      270.0
DST 2 PH 1   85.50   25.0      280.0
DST 2 PH 1   85.50   10.0      280.0
DST 2 PH 1   85.50    5.0      280.0
DST 2 PH 1   85.50    1.0      280.0
DST 2 PH 1   85.50   25.0      270.0
DST 2 PH 1   85.50   10.0      270.0
DST 2 PH 1   85.50    5.0      270.0
DST 2 PH 1   85.50    1.0      270.0
DST-1
```

Table 7. Output for Precipitation Model Test Case 1

1 TEST CASE 1 - PRECIPITATION MODEL

FREQ (GHZ)	RAINRATE (MM/HR)	TEMP DEG K	PHASE	DIST	ERR	ABSORPTION COEFFICIENT	EXTINCTION COEFFICIENT	FIRST EIGHT LEGENDRE COEFFICIENTS 1	2	3	4	5	6	7	8
19.35	25.00	280.0	1	1	0	.414659	.540789	1.0000	-.1931	.4814	.0392	.0028	.0000	.0000	.0000
19.35	10.00	280.0	1	1	0	.159046	.195916	1.0000	-.1326	.4871	.0288	.0013	.0000	.0000	.0000
19.35	5.00	280.0	1	1	0	.077040	.090887	1.0000	-.0904	.4914	.0228	.0007	.0000	.0000	.0000
19.35	1.00	280.0	1	1	0	.014315	.015276	1.0000	-.0318	.5015	.0133	.0002	.0000	.0000	.0000
19.35	25.00	270.0	1	1	0	.403235	.527515	1.0000	-.1126	.4865	.0392	.0027	.0000	.0000	.0000
19.35	10.00	270.0	1	1	0	.156786	.193305	1.0000	-.0680	.4909	.0288	.0013	.0000	.0000	.0000
19.35	5.00	270.0	1	1	0	.076732	.090456	1.0000	-.0443	.4943	.0229	.0007	.0000	.0000	.0000
19.35	1.00	270.0	1	1	0	.014603	.015513	1.0000	-.0150	.5023	.0133	.0002	.0000	.0000	.0000
19.35	25.00	280.0	1	2	0	.368940	.542354	1.0000	-.1582	.4778	.0486	.0038	.0002	.0000	.0000
19.35	10.00	280.0	1	2	0	.143296	.192833	1.0000	-.1209	.4849	.0340	.0015	.0001	.0000	.0000
19.35	5.00	280.0	1	2	0	.070070	.088196	1.0000	-.0841	.4903	.0260	.0008	.0000	.0000	.0000
19.35	1.00	280.0	1	2	0	.013308	.014342	1.0000	-.0293	.5032	.0139	.0002	.0000	.0000	.0000
19.35	25.00	270.0	1	2	0	.368940	.542354	1.0000	-.1582	.4778	.0486	.0038	.0002	.0000	.0000
19.35	10.00	270.0	1	2	0	.143296	.192833	1.0000	-.1209	.4849	.0340	.0015	.0001	.0000	.0000
19.35	5.00	270.0	1	2	0	.070070	.088196	1.0000	-.0841	.4903	.0260	.0008	.0000	.0000	.0000
19.35	1.00	270.0	1	2	0	.013308	.014342	1.0000	-.0293	.5032	.0139	.0002	.0000	.0000	.0000
37.00	25.00	280.0	1	1	0	1.011683	1.738191	1.0000	.1408	.4730	.0979	.0288	.0051	.0000	.0000
37.00	10.00	280.0	1	1	0	.436165	.708936	1.0000	.0699	.4791	.0805	.0144	.0019	.0000	.0000
37.00	5.00	280.0	1	1	0	.230805	.359798	1.0000	.0442	.4839	.0696	.0085	.0009	.0000	.0000
37.00	1.00	280.0	1	1	0	.052658	.074547	1.0000	.0190	.4950	.0501	.0025	.0002	.0000	.0000
37.00	25.00	270.0	1	1	0	1.064207	1.789098	1.0000	.2184	.4892	.1052	.0298	.0053	.0000	.0000
37.00	10.00	270.0	1	1	0	.456383	.710412	1.0000	.1643	.4919	.0785	.0147	.0020	.0000	.0000
37.00	5.00	270.0	1	1	0	.240535	.353242	1.0000	.1328	.4939	.0629	.0087	.0009	.0000	.0000
37.00	1.00	270.0	1	1	0	.054366	.069745	1.0000	.0813	.4985	.0376	.0025	.0002	.0000	.0000
37.00	25.00	280.0	1	2	0	.775747	1.463156	1.0000	.3243	.4809	.1525	.0583	.0114	.0000	.0000
37.00	10.00	280.0	1	2	0	.351828	.604646	1.0000	.1944	.4846	.1047	.0239	.0031	.0000	.0000
37.00	5.00	280.0	1	2	0	.193448	.309867	1.0000	.1320	.4875	.0788	.0122	.0011	.0000	.0000
37.00	1.00	280.0	1	2	0	.048240	.065624	1.0000	.0537	.4942	.0407	.0025	.0001	.0000	.0000
37.00	25.00	270.0	1	2	0	.775747	1.463156	1.0000	.3243	.4809	.1525	.0583	.0114	.0000	.0000
37.00	10.00	270.0	1	2	0	.351828	.604646	1.0000	.1944	.4846	.1047	.0239	.0031	.0000	.0000
37.00	5.00	270.0	1	2	0	.193448	.309867	1.0000	.1320	.4875	.0788	.0122	.0011	.0000	.0000
37.00	1.00	270.0	1	2	0	.048240	.065624	1.0000	.0537	.4942	.0407	.0025	.0001	.0000	.0000
85.50	25.00	280.0	1	1	0	1.804524	3.500282	1.0000	.9894	.8951	.5586	.3546	.1856	.0993	.0482

85.50	10.00	280.0	1	1	0	.927913	1.716124	1.0000	.8244	.7779	.3927	.2139	.0903	.0388	.0147
85.50	5.00	280.0	1	1	0	.561374	1.001734	1.0000	.7185	.7000	.3008	.1460	.0524	.0191	.0060
85.50	1.00	280.0	1	1	0	.175081	.287716	1.0000	.5229	.5494	.1620	.0601	.0148	.0037	.0007
85.50	25.00	270.0	1	1	0	1.862917	3.480667	1.0000	1.0772	.9569	.6007	.3758	.1963	.1039	.0508
85.50	10.00	270.0	1	1	0	.950667	1.694109	1.0000	.9183	.8267	.4217	.2255	.0950	.0406	.0151
85.50	5.00	270.0	1	1	0	.571825	.983369	1.0000	.8140	.7406	.3227	.1533	.0549	.0200	.0061
85.50	1.00	270.0	1	1	0	.175955	.278743	1.0000	.6156	.5751	.1733	.0626	.0154	.0038	.0007
85.50	25.00	280.0	1	2	0	1.117447	2.178297	1.0000	1.2961	1.2622	.9555	.6815	.4367	.2677	.1490
85.50	10.00	280.0	1	2	0	.600745	1.124462	1.0000	1.0926	1.0276	.6432	.3940	.1957	.0926	.0369
85.50	5.00	280.0	1	2	0	.375842	.682377	1.0000	.9609	.8801	.4768	.2605	.1067	.0414	.0128
85.50	1.00	280.0	1	2	0	.126679	.214429	1.0000	.7147	.6159	.2379	.0999	.0262	.0064	.0011
85.50	25.00	270.0	1	2	0	1.117447	2.178297	1.0000	1.2961	1.2622	.9555	.6815	.4367	.2677	.1490
85.50	10.00	270.0	1	2	0	.600745	1.124462	1.0000	1.0926	1.0276	.6432	.3940	.1957	.0926	.0369
85.50	5.00	270.0	1	2	0	.375842	.682377	1.0000	.9609	.8801	.4768	.2605	.1067	.0414	.0128
85.50	1.00	270.0	1	2	0	.126679	.214429	1.0000	.7147	.6159	.2379	.0999	.0262	.0064	.0011

Table 8. Input for Precipitation Model Test Case 1

```
 TEST CASE 2A - CALM OCEAN - TROPICAL
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 1 AI 1 WF 1 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 1 RN 1
GRN 0 ET 1   300.0     300.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 10.60           0.000   0.000
 18.00           0.000   0.000
 -1.             -1.     -1.
RPT 1
 TEST CASE 2B - WET SNOWPACK - MID-LATITUDE WINTER
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  272.20
MOD 3 RH 3 CL 1 RN 1
GRN 4 ET 1   273.0     273.0
  0.0                                                                    -1.
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 10.60           0.000   0.000
 18.00           0.000   0.000
 -1.             -1.     -1.
RPT 1
 TEST CASE 2C - VEGETATION (MV=0.1) - U.S. STANDARD
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  288.00
MOD 6 RH 6 CL 1 RN 1
GRN 5 ET 1   288.0     286.0
  0.0                                                                    -1.
  0.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 10.60           0.000   0.000
 18.00           0.000   0.000
 -1.             -1.     -1.
RPT 1
 TEST CASE 2D - WET SOIL - U.S. STANDARD
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  288.00
MOD 6 RH 6 CL 1 RN 1
GRN 6 ET 1   288.0     288.0
  0.0                                                                    -1.
  0.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 10.60           0.000   0.000
 18.00           0.000   0.000
 -1.             -1.     -1.
RPT 0
```

Table 9. Output For Surface Model Test Case 2

1 TEST CASE 2A - CALM OCEAN - TROPICAL

ATMOSPHERIC PROFILE - TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	.000
.500	958.50	297.00	.7500	.0000	.000
1.000	904.00	294.00	.7500	.0000	.000
1.500	854.50	291.00	.7500	.0000	.000
2.000	805.00	288.00	.7500	.0000	.000
2.500	760.00	286.00	.3500	.0000	.000
3.000	715.00	284.00	.3500	.0000	.000
3.500	674.00	280.50	.3500	.0000	.000
4.000	633.00	277.00	.3500	.0000	.000
5.000	559.00	270.00	.3500	.0000	.000
6.000	492.00	264.00	.3500	.0000	.000
7.000	432.00	257.00	.3000	.0000	.000
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000
12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000

30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000
40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 1 MRAIN = 1 TGRND = 300.00

GROUND = 0 TEMP1 = 300.00
1WATER-VAPOR ROTATIONAL SPECTRAL LINE PARAMETERS NLINES= 54

DESIGNATION	FREQ,GHZ	PARITY	STRENGTH	TERM1	TERM2	WDAIR	WDH2O	TEXP
5,23-6,16	22.23520	EOOE	.0549	446.39	447.17	.09019	.47770	.626
2,20-3,13	183.31010	EEOO	.1015	136.15	142.30	.09600	.49370	.649
9,36-10,29	323.15850	OEEO	.0870	1283.02	1293.80	.07652	.40120	.420
4,22-5,15	323.75810	EEOO	.0891	315.70	326.50	.09292	.50710	.619
3,21-4,14	377.41800	EOOE	.1224	212.12	224.71	.09480	.52800	.630
11,210-10,37	389.70880	EEOO	.0680	1525.31	1538.31	.07020	.38070	.330
6,60-7,53	435.87430	EEOO	.0820	1045.14	1059.68	.05000	.26480	.290
5,50-6,43	437.67300	OEEO	.0987	742.18	756.78	.05900	.34800	.360
6,61-7,52	441.57000	EOOE	.0820	1045.14	1059.87	.05023	.27090	.332
3,30-4,23	445.76690	OEEO	.1316	285.46	300.33	.08247	.47480	.510
5,51-6,42	465.85190	OOEE	.0990	742.18	757.72	.06290	.35210	.380
4,40-5,33	470.94810	EEOO	.1165	488.19	503.90	.06900	.39870	.380
7,17-6,24	487.13600	OOEE	.0330	586.46	602.71	.08610	.49260	.510
7,70-8,63	498.52750	OEEO	.0770	1394.96	1411.59	.04240	.20510	.320
7,71-8,62	498.52750	OOEE	.0720	1394.96	1411.59	.04240	.20500	.340
1,01-1,10	557.58340	EOOE	1.5000	23.76	42.36	.11115	.48890	.645
4,41-5,32	617.83830	EOOE	.1193	488.19	508.80	.07606	.42620	.600
8,80-9,73	641.52060	EEOO	.0660	1789.36	1810.76	.03800	.17200	.400
8,81-9,72	641.52060	EOOE	.0660	1789.36	1810.76	.03800	.17150	.400
2,02-2,11	752.73750	EEOO	2.0739	70.08	95.19	.10440	.46480	.690
8,35-9,28	833.07750	OOEE	.1570	1052.72	1080.51	.07980	.42970	.510
11,29-10,56	857.95890	EOOE	.0670	1690.74	1719.36	.05500	.30900	.200
9,90-10,83	859.15800	OEEO	.0590	2225.87	2254.53	.03570	.15350	.480
9,91-10,82	859.15800	OOEE	.0590	2225.87	2254.53	.03570	.15350	.480
3,31-4,22	912.51810	OOEE	.1613	285.26	315.70	.08638	.46890	.676
4,31-5,24	961.38160	OOEE	.2622	383.93	416.00	.08262	.47220	.560

1,11-2,02	987.46210	OOEE	.7557	37.14	70.08	.10316	.50690	.660
12,211-11,38	1077.39490	EOOE	.0420	1774.85	1810.79	.06100	.34760	.250
3,03-3,12	1098.37930	EOOE	2.1809	136.74	173.38	.09944	.55900	.701
10,29-9,55	1107.67230	EEOO	.0500	1438.19	1475.14	.06100	.63100	.250
0,00-1,11	1113.36810	EEOO	1.0000	.00	37.14	.10034	.50260	.689
10,100-11,93	1142.74610	EEOO	.0540	2702.61	2740.73	.03434	.12970	.503
10,101-11,92	1142.74610	EOOE	.0540	2702.61	2740.73	.03434	.12970	.503
8,18-7,25	1145.74390	OEEO	.0250	744.20	782.42	.08008	.45630	.498
2,21-3,32	1154.13760	EOOE	.3003	134.88	173.38	.09515	.54850	.610
5,41-6,34	1159.83330	EOOE	.2784	610.34	649.03	.07131	.42290	.399
3,12-3,21	1161.33220	OEEO	2.5434	173.38	212.12	.09487	.50600	.682
7,61-8,54	1163.43070	EOOE	.2230	1216.38	1255.19	.05160	.29080	.290
6,51-7,44	1169.72600	OOEE	.2520	888.74	927.76	.06480	.37400	.360
7,62-8,53	1187.11300	EEOO	.2230	1216.38	1255.98	.05420	.30610	.300
8,71-9,64	1208.99660	OOEE	.1990	1591.11	1631.44	.04450	.23810	.320
8,72-9,63	1213.19350	OEEO	.1990	1591.11	1631.58	.04470	.24110	.340
4,13-4,22	1213.19350	OOEE	3.6547	272.23	315.70	.09507	.50910	.720
2,11-2,20	1227.88250	OOEE	1.2594	95.19	136.15	.09792	.46580	.670
6,52-7,43	1227.94510	OEEO	.2530	888.70	931.33	.06880	.26820	.450
7,34-8,27	1294.43280	OEEO	.1840	842.51	885.69	.08190	.45770	.550
9,18-8,45	1309.72130	OEEO	.0470	1079.20	1122.89	.06000	.34800	.250
5,32-6,25	1323.21130	OEEO	.3117	508.80	552.94	.08313	.49390	.571
9,81-10,74	1329.80630	EOOE	.1730	2010.19	2054.55	.03900	.20770	.390
9,82-10,73	1329.80630	EEOO	.1730	2010.19	2054.55	.03900	.20770	.390
8,17-7,44	1342.69670	OOEE	.0360	882.97	927.76	.06600	.37500	.300
5,14-5,23	1407.44830	OEEO	4.2239	399.44	446.39	.09470	.51230	.722
10,19-9,46	1423.33640	OOEE	.0590	1293.22	1340.70	.05500	.32200	.240
6,33-7,26	1435.92700	OOEE	.2580	661.54	709.44	.08300	.46420	.590

1 ATMOSPHERIC ATTENUATION BY OXYGEN, WATER VAPOR AND CONDENSED WATER

TEST CASE 2A - CALM OCEAN - TROPICAL

FREQUENCY = 10.60 GHZ

HEIGHT	PRESSURE	H2O DENSITY	ATTENUATION COEFFICIENT (DB/KM)				
					CONDENSED WATER		
(KM)	(TORR)	(GM/CU M)	OXYGEN	WATER VAPOR	CLOUDS	RAIN	TOTAL
.000	759.81	19.2964	7.238E-03	1.946E-02	0.000E+00	0.000E+00	2.670E-02

.250	739.09	17.7330	6.949E-03	1.748E-02	0.000E+00	0.000E+00	2.443E-02
.500	718.93	16.2820	6.672E-03	1.569E-02	0.000E+00	0.000E+00	2.236E-02
.750	698.20	14.9363	6.386E-03	1.406E-02	0.000E+00	0.000E+00	2.044E-02
1.000	678.06	13.6895	6.112E-03	1.258E-02	0.000E+00	0.000E+00	1.869E-02
1.250	659.23	12.5351	5.864E-03	1.126E-02	0.000E+00	0.000E+00	1.713E-02
1.500	640.93	11.4675	5.626E-03	1.008E-02	0.000E+00	0.000E+00	1.570E-02
1.750	622.09	10.4807	5.380E-03	8.992E-03	0.000E+00	0.000E+00	1.437E-02
2.000	603.80	9.5697	5.146E-03	8.019E-03	0.000E+00	0.000E+00	1.316E-02
2.250	586.68	6.6014	4.907E-03	5.330E-03	0.000E+00	0.000E+00	1.024E-02
2.500	570.05	3.9499	4.680E-03	3.075E-03	0.000E+00	0.000E+00	7.756E-03
2.750	552.91	3.7122	4.448E-03	2.820E-03	0.000E+00	0.000E+00	7.268E-03
3.000	536.29	3.4873	4.228E-03	2.584E-03	0.000E+00	0.000E+00	6.812E-03
3.250	520.69	3.1226	4.057E-03	2.268E-03	0.000E+00	0.000E+00	6.325E-03
3.500	505.54	2.7920	3.894E-03	1.988E-03	0.000E+00	0.000E+00	5.882E-03
3.750	489.92	2.4929	3.724E-03	1.737E-03	0.000E+00	0.000E+00	5.461E-03
4.000	474.79	2.2225	3.562E-03	1.516E-03	0.000E+00	0.000E+00	5.078E-03
4.500	446.17	1.7585	3.263E-03	1.150E-03	0.000E+00	0.000E+00	4.413E-03
5.000	419.28	1.3522	2.991E-03	8.485E-04	0.000E+00	0.000E+00	3.839E-03
5.500	393.36	1.0712	2.719E-03	6.422E-04	0.000E+00	0.000E+00	3.361E-03
6.000	369.03	.8345	2.472E-03	4.781E-04	0.000E+00	0.000E+00	2.950E-03
6.500	345.80	.5661	2.256E-03	3.105E-04	0.000E+00	0.000E+00	2.567E-03
7.000	324.03	.3765	2.060E-03	1.979E-04	0.000E+00	0.000E+00	2.258E-03
7.500	303.10	.2745	1.875E-03	1.381E-04	0.000E+00	0.000E+00	2.013E-03
8.000	283.52	.1983	1.708E-03	9.553E-05	0.000E+00	0.000E+00	1.804E-03
8.500	264.51	.1365	1.545E-03	6.262E-05	0.000E+00	0.000E+00	1.608E-03
9.000	246.77	.0925	1.429E-03	4.044E-05	0.000E+00	0.000E+00	1.469E-03
9.500	230.08	.0586	1.327E-03	2.446E-05	0.000E+00	0.000E+00	1.351E-03
10.000	214.52	.0362	1.232E-03	1.447E-05	0.000E+00	0.000E+00	1.247E-03
10.500	199.36	.0125	1.138E-03	4.746E-06	0.000E+00	0.000E+00	1.143E-03
11.000	185.27	.0000	1.052E-03	0.000E+00	0.000E+00	0.000E+00	1.052E-03
11.500	172.04	.0000	9.643E-04	0.000E+00	0.000E+00	0.000E+00	9.643E-04
12.000	159.76	.0000	8.842E-04	0.000E+00	0.000E+00	0.000E+00	8.842E-04
12.500	147.68	.0000	8.097E-04	0.000E+00	0.000E+00	0.000E+00	8.097E-04
13.000	136.51	.0000	7.417E-04	0.000E+00	0.000E+00	0.000E+00	7.417E-04
13.500	126.38	.0000	6.813E-04	0.000E+00	0.000E+00	0.000E+00	6.813E-04
14.000	117.01	.0000	6.260E-04	0.000E+00	0.000E+00	0.000E+00	6.260E-04
14.500	107.63	.0000	5.651E-04	0.000E+00	0.000E+00	0.000E+00	5.651E-04
15.000	99.01	.0000	5.101E-04	0.000E+00	0.000E+00	0.000E+00	5.101E-04
15.500	90.79	.0000	4.614E-04	0.000E+00	0.000E+00	0.000E+00	4.614E-04
16.000	83.26	.0000	4.175E-04	0.000E+00	0.000E+00	0.000E+00	4.175E-04

16.500	76.49	.0000	3.654E-04	0.000E+00	0.000E+00	0.000E+00	3.654E-04
17.000	70.28	.0000	3.197E-04	0.000E+00	0.000E+00	0.000E+00	3.197E-04
17.500	64.49	.0000	2.669E-04	0.000E+00	0.000E+00	0.000E+00	2.669E-04
18.000	59.18	.0000	2.228E-04	0.000E+00	0.000E+00	0.000E+00	2.228E-04
18.500	54.37	.0000	1.863E-04	0.000E+00	0.000E+00	0.000E+00	1.863E-04
19.000	49.95	.0000	1.558E-04	0.000E+00	0.000E+00	0.000E+00	1.558E-04
19.500	46.01	.0000	1.309E-04	0.000E+00	0.000E+00	0.000E+00	1.309E-04
20.000	42.38	.0000	1.099E-04	0.000E+00	0.000E+00	0.000E+00	1.099E-04
20.500	39.06	.0000	9.246E-05	0.000E+00	0.000E+00	0.000E+00	9.246E-05
21.000	36.00	.0000	7.775E-05	0.000E+00	0.000E+00	0.000E+00	7.775E-05
21.500	33.23	.0000	6.556E-05	0.000E+00	0.000E+00	0.000E+00	6.556E-05
22.000	30.68	.0000	5.527E-05	0.000E+00	0.000E+00	0.000E+00	5.527E-05
22.500	28.38	.0000	4.741E-05	0.000E+00	0.000E+00	0.000E+00	4.741E-05
23.000	26.25	.0000	4.066E-05	0.000E+00	0.000E+00	0.000E+00	4.066E-05
23.500	24.30	.0000	3.491E-05	0.000E+00	0.000E+00	0.000E+00	3.491E-05
24.000	22.50	.0000	2.998E-05	0.000E+00	0.000E+00	0.000E+00	2.998E-05
24.500	20.83	.0000	2.572E-05	0.000E+00	0.000E+00	0.000E+00	2.572E-05
25.000	19.28	.0000	2.206E-05	0.000E+00	0.000E+00	0.000E+00	2.206E-05
27.500	13.28	.0000	9.786E-06	0.000E+00	0.000E+00	0.000E+00	9.786E-06
30.000	9.15	.0000	4.335E-06	0.000E+00	0.000E+00	0.000E+00	4.335E-06
32.500	6.42	.0000	1.993E-06	0.000E+00	0.000E+00	0.000E+00	1.993E-06
35.000	4.50	.0000	9.174E-07	0.000E+00	0.000E+00	0.000E+00	9.174E-07
37.500	3.21	.0000	4.372E-07	0.000E+00	0.000E+00	0.000E+00	4.372E-07
40.000	2.29	.0000	2.086E-07	0.000E+00	0.000E+00	0.000E+00	2.086E-07
42.500	1.65	.0000	1.023E-07	0.000E+00	0.000E+00	0.000E+00	1.023E-07
45.000	1.19	.0000	5.018E-08	0.000E+00	0.000E+00	0.000E+00	5.018E-08
47.500	.87	.0000	2.623E-08	0.000E+00	0.000E+00	0.000E+00	2.623E-08

1 TEST CASE 2A - CALM OCEAN - TROPICAL

ATMOSPHERIC TRANSMISSION AND WEIGHTING FUNCTIONS

FREQUENCY = 10.60 GHZ ANGLE = 54.00 DEGREES

HEIGHT (KM)	PRESSURE (TORR)	TRANSMISSION H TO SPACE	TRANSMISSION H TO GROUND	WEIGHTING FUCNTIONS GROUND BASED	SPACE BASED
.000	759.81	1.0000E+00	9.6979E-01	6.1398E-03	1.0157E-02
.250	739.09	9.9739E-01	9.7233E-01	1.1744E-02	9.3167E-03
.500	718.93	9.9501E-01	9.7466E-01	1.6862E-02	8.5481E-03

.750	698.20	9.9283E-01	9.7680E-01	2.1530E-02	7.8294E-03
1.000	678.06	9.9084E-01	9.7875E-01	2.5791E-02	7.1733E-03
1.250	659.23	9.8903E-01	9.8055E-01	2.9687E-02	6.5839E-03
1.500	640.93	9.8737E-01	9.8219E-01	3.3254E-02	6.0457E-03
1.750	622.09	9.8586E-01	9.8371E-01	3.6514E-02	5.5422E-03
2.000	603.80	9.8447E-01	9.8509E-01	3.9497E-02	5.0833E-03
2.250	586.68	9.8320E-01	9.8636E-01	4.1813E-02	3.9576E-03
2.500	570.05	9.8222E-01	9.8735E-01	4.3566E-02	3.0008E-03
2.750	552.91	9.8147E-01	9.8810E-01	4.5208E-02	2.8142E-03
3.000	536.29	9.8077E-01	9.8880E-01	4.6746E-02	2.6395E-03
3.250	520.69	9.8012E-01	9.8946E-01	4.8173E-02	2.4525E-03
3.500	505.54	9.7951E-01	9.9008E-01	4.9499E-02	2.2820E-03
3.750	489.92	9.7895E-01	9.9065E-01	5.0730E-02	2.1198E-03
4.000	474.79	9.7842E-01	9.9118E-01	2.6508E-02	1.9725E-03
4.500	446.17	9.7745E-01	9.9216E-01	2.7501E-02	1.7160E-03
5.000	419.28	9.7661E-01	9.9302E-01	2.8364E-02	1.4940E-03
5.500	393.36	9.7587E-01	9.9377E-01	2.9119E-02	1.3088E-03
6.000	369.03	9.7523E-01	9.9442E-01	2.9781E-02	1.1497E-03
6.500	345.80	9.7467E-01	9.9500E-01	3.0357E-02	1.0007E-03
7.000	324.03	9.7418E-01	9.9550E-01	3.0864E-02	8.8066E-04
7.500	303.10	9.7375E-01	9.9594E-01	3.1315E-02	7.8563E-04
8.000	283.52	9.7336E-01	9.9633E-01	3.1719E-02	[illegible].0404E-04
8.500	264.51	9.7302E-01	9.9668E-01	3.2079E-02	6.2795E-04
9.000	246.77	9.7271E-01	9.9700E-01	3.2408E-02	5.7378E-04
9.500	230.08	9.7243E-01	9.9728E-01	3.2711E-02	5.2793E-04
10.000	214.52	9.7217E-01	9.9755E-01	3.2990E-02	4.8723E-04
10.500	199.36	9.7194E-01	9.9779E-01	3.3246E-02	4.4684E-04
11.000	185.27	9.7172E-01	9.9802E-01	3.3481E-02	4.1119E-04
11.500	172.04	9.7152E-01	9.9822E-01	3.3697E-02	3.7712E-04
12.000	159.76	9.7134E-01	9.9841E-01	3.3894E-02	3.4585E-04
12.500	147.68	9.7117E-01	9.9858E-01	3.4075E-02	3.1677E-04
13.000	136.51	9.7101E-01	9.9874E-01	3.4241E-02	2.9018E-04
13.500	126.38	9.7087E-01	9.9889E-01	3.4393E-02	2.6660E-04
14.000	117.01	9.7074E-01	9.9902E-01	3.4533E-02	2.4500E-04
14.500	107.63	9.7062E-01	9.9914E-01	3.4660E-02	2.2118E-04
15.000	99.01	9.7052E-01	9.9925E-01	3.4774E-02	1.9970E-04
15.500	90.79	9.7042E-01	9.9935E-01	3.4877E-02	1.8064E-04
16.000	83.26	9.7033E-01	9.9944E-01	3.4970E-02	1.6347E-04
16.500	76.49	9.7025E-01	9.9952E-01	3.5052E-02	1.4308E-04
17.000	70.28	9.7018E-01	9.9960E-01	3.5123E-02	1.2518E-04

17.500	64.49	9.7012E-01	9.9966E-01	3.5183E-02	1.0451E-04
18.000	59.18	9.7007E-01	9.9971E-01	3.5232E-02	8.7238E-05
18.500	54.37	9.7003E-01	9.9975E-01	3.5274E-02	7.2970E-05
19.000	49.95	9.6999E-01	9.9979E-01	3.5309E-02	6.1029E-05
19.500	46.01	9.6996E-01	9.9982E-01	3.5338E-02	5.1265E-05
20.000	42.38	9.6994E-01	9.9985E-01	3.5363E-02	4.3061E-05
20.500	39.06	9.6992E-01	9.9987E-01	3.5383E-02	3.6214E-05
21.000	36.00	9.6990E-01	9.9989E-01	3.5401E-02	3.0454E-05
21.500	33.23	9.6989E-01	9.9990E-01	3.5415E-02	2.5678E-05
22.000	30.68	9.6987E-01	9.9992E-01	3.5428E-02	2.1651E-05
22.500	28.38	9.6986E-01	9.9993E-01	3.5438E-02	1.8571E-05
23.000	26.25	9.6985E-01	9.9994E-01	3.5447E-02	1.5926E-05
23.500	24.30	9.6985E-01	9.9994E-01	3.5455E-02	1.3676E-05
24.000	22.50	9.6984E-01	9.9995E-01	3.5462E-02	1.1742E-05
24.500	20.83	9.6983E-01	9.9996E-01	3.5467E-02	1.0075E-05
25.000	19.28	9.6983E-01	9.9996E-01	7.0984E-03	8.6429E-06
27.500	13.28	9.6981E-01	9.9998E-01	7.1006E-03	3.8334E-06
30.000	9.15	9.6980E-01	9.9999E-01	7.1016E-03	1.6981E-06
32.500	6.42	9.6980E-01	1.0000E+00	7.1020E-03	7.8055E-07
35.000	4.50	9.6979E-01	1.0000E+00	7.1022E-03	3.5935E-07
37.500	3.21	9.6979E-01	1.0000E+00	7.1023E-03	1.7126E-07
40.000	2.29	9.6979E-01	1.0000E+00	7.1024E-03	8.1732E-08
42.500	1.65	9.6979E-01	1.0000E+00	7.1024E-03	4.0057E-08
45.000	1.19	9.6979E-01	1.0000E+00	7.1024E-03	1.9657E-08
47.500	.87	9.6979E-01	1.0000E+00	7.1024E-03	1.0276E-08
50.000	.64	9.6979E-01	1.0000E+00		

1 TEST CASE 2A - CALM OCEAN - TROPICAL

FREQUENCY = 10.60 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.3067E-01	.96979	8.43452	85.39591	173.40154	.24322	.55446

1 ATMOSPHERIC ATTENUATION BY OXYGEN, WATER VAPOR AND CONDENSED WATER

TEST CASE 2A - CALM OCEAN - TROPICAL

FREQUENCY = 18.00 GHZ

HEIGHT	PRESSURE	H2O DENSITY	ATTENUATION COEFFICIENT (DB/KM)				
					CONDENSED WATER		
(KM)	(TORR)	(GM/CU M)	OXYGEN	WATER VAPOR	CLOUDS	RAIN	TOTAL
.000	759.81	19.2964	8.348E-03	1.202E-01	0.000E+00	0.000E+00	1.285E-01
.250	739.09	17.7330	8.014E-03	1.090E-01	0.000E+00	0.000E+00	1.170E-01
.500	718.93	16.2820	7.693E-03	9.871E-02	0.000E+00	0.000E+00	1.064E-01
.750	698.20	14.9363	7.362E-03	8.922E-02	0.000E+00	0.000E+00	9.658E-02
1.000	678.06	13.6895	7.046E-03	8.053E-02	0.000E+00	0.000E+00	8.758E-02
1.250	659.23	12.5351	6.759E-03	7.264E-02	0.000E+00	0.000E+00	7.940E-02
1.500	640.93	11.4675	6.484E-03	6.545E-02	0.000E+00	0.000E+00	7.193E-02
1.750	622.09	10.4807	6.200E-03	5.883E-02	0.000E+00	0.000E+00	6.503E-02
2.000	603.80	9.5697	5.929E-03	5.281E-02	0.000E+00	0.000E+00	5.874E-02
2.250	586.68	6.6014	5.654E-03	3.547E-02	0.000E+00	0.000E+00	4.112E-02
2.500	570.05	3.9499	5.392E-03	2.066E-02	0.000E+00	0.000E+00	2.605E-02
2.750	552.91	3.7122	5.124E-03	1.905E-02	0.000E+00	0.000E+00	2.417E-02
3.000	536.29	3.4873	4.869E-03	1.755E-02	0.000E+00	0.000E+00	2.242E-02
3.250	520.69	3.1226	4.672E-03	1.546E-02	0.000E+00	0.000E+00	2.013E-02
3.500	505.54	2.7920	4.484E-03	1.359E-02	0.000E+00	0.000E+00	1.807E-02
3.750	489.92	2.4929	4.288E-03	1.191E-02	0.000E+00	0.000E+00	1.619E-02
4.000	474.79	2.2225	4.100E-03	1.042E-02	0.000E+00	0.000E+00	1.452E-02
4.500	446.17	1.7585	3.756E-03	7.935E-03	0.000E+00	0.000E+00	1.169E-02
5.000	419.28	1.3522	3.442E-03	5.867E-03	0.000E+00	0.000E+00	9.309E-03
5.500	393.36	1.0712	3.128E-03	4.452E-03	0.000E+00	0.000E+00	7.581E-03
6.000	369.03	.8345	2.844E-03	3.320E-03	0.000E+00	0.000E+00	6.164E-03
6.500	345.80	.5661	2.595E-03	2.154E-03	0.000E+00	0.000E+00	4.749E-03
7.000	324.03	.3765	2.369E-03	1.370E-03	0.000E+00	0.000E+00	3.739E-03
7.500	303.10	.2745	2.156E-03	9.535E-04	0.000E+00	0.000E+00	3.110E-03
8.000	283.52	.1983	1.963E-03	6.571E-04	0.000E+00	0.000E+00	2.621E-03
8.500	264.51	.1365	1.776E-03	4.294E-04	0.000E+00	0.000E+00	2.206E-03
9.000	246.77	.0925	1.642E-03	2.762E-04	0.000E+00	0.000E+00	1.918E-03
9.500	230.08	.0586	1.524E-03	1.660E-04	0.000E+00	0.000E+00	1.690E-03
10.000	214.52	.0362	1.416E-03	9.746E-05	0.000E+00	0.000E+00	1.513E-03
10.500	199.36	.0125	1.307E-03	3.172E-05	0.000E+00	0.000E+00	1.339E-03
11.000	185.27	.0000	1.208E-03	0.000E+00	0.000E+00	0.000E+00	1.208E-03

11.500	172.04	.0000	1.107E-03	0.000E+00	0.000E+00	0.000E+00	1.107E-03
12.000	159.76	.0000	1.015E-03	0.000E+00	0.000E+00	0.000E+00	1.015E-03
12.500	147.68	.0000	9.295E-04	0.000E+00	0.000E+00	0.000E+00	9.295E-04
13.000	136.51	.0000	8.512E-04	0.000E+00	0.000E+00	0.000E+00	8.512E-04
13.500	126.38	.0000	7.817E-04	0.000E+00	0.000E+00	0.000E+00	7.817E-04
14.000	117.01	.0000	7.182E-04	0.000E+00	0.000E+00	0.000E+00	7.182E-04
14.500	107.63	.0000	6.482E-04	0.000E+00	0.000E+00	0.000E+00	6.482E-04
15.000	99.01	.0000	5.851E-04	0.000E+00	0.000E+00	0.000E+00	5.851E-04
15.500	90.79	.0000	5.291E-04	0.000E+00	0.000E+00	0.000E+00	5.291E-04
16.000	83.26	.0000	4.786E-04	0.000E+00	0.000E+00	0.000E+00	4.786E-04
16.500	76.49	.0000	4.189E-04	0.000E+00	0.000E+00	0.000E+00	4.189E-04
17.000	70.28	.0000	3.664E-04	0.000E+00	0.000E+00	0.000E+00	3.664E-04
17.500	64.49	.0000	3.059E-04	0.000E+00	0.000E+00	0.000E+00	3.059E-04
18.000	59.18	.0000	2.554E-04	0.000E+00	0.000E+00	0.000E+00	2.554E-04
18.500	54.37	.0000	2.136E-04	0.000E+00	0.000E+00	0.000E+00	2.136E-04
19.000	49.95	.0000	1.787E-04	0.000E+00	0.000E+00	0.000E+00	1.787E-04
19.500	46.01	.0000	1.501E-04	0.000E+00	0.000E+00	0.000E+00	1.501E-04
20.000	42.38	.0000	1.261E-04	0.000E+00	0.000E+00	0.000E+00	1.261E-04
20.500	39.06	.0000	1.061E-04	0.000E+00	0.000E+00	0.000E+00	1.061E-04
21.000	36.00	.0000	8.919E-05	0.000E+00	0.000E+00	0.000E+00	8.919E-05
21.500	33.23	.0000	7.521E-05	0.000E+00	0.000E+00	0.000E+00	7.521E-05
22.000	30.68	.0000	6.342E-05	0.000E+00	0.000E+00	0.000E+00	6.342E-05
22.500	28.38	.0000	5.440E-05	0.000E+00	0.000E+00	0.000E+00	5.440E-05
23.000	26.25	.0000	4.666E-05	0.000E+00	0.000E+00	0.000E+00	4.666E-05
23.500	24.30	.0000	4.007E-05	0.000E+00	0.000E+00	0.000E+00	4.007E-05
24.000	22.50	.0000	3.440E-05	0.000E+00	0.000E+00	0.000E+00	3.440E-05
24.500	20.83	.0000	2.952E-05	0.000E+00	0.000E+00	0.000E+00	2.952E-05
25.000	19.28	.0000	2.532E-05	0.000E+00	0.000E+00	0.000E+00	2.532E-05
27.500	13.28	.0000	1.123E-05	0.000E+00	0.000E+00	0.000E+00	1.123E-05
30.000	9.15	.0000	4.977E-06	0.000E+00	0.000E+00	0.000E+00	4.977E-06
32.500	6.42	.0000	2.288E-06	0.000E+00	0.000E+00	0.000E+00	2.288E-06
35.000	4.50	.0000	1.054E-06	0.000E+00	0.000E+00	0.000E+00	1.054E-06
37.500	3.21	.0000	5.023E-07	0.000E+00	0.000E+00	0.000E+00	5.023E-07
40.000	2.29	.0000	2.398E-07	0.000E+00	0.000E+00	0.000E+00	2.398E-07
42.500	1.65	.0000	1.175E-07	0.000E+00	0.000E+00	0.000E+00	1.175E-07
45.000	1.19	.0000	5.769E-08	0.000E+00	0.000E+00	0.000E+00	5.769E-08
47.500	.87	.0000	3.016E-08	0.000E+00	0.000E+00	0.000E+00	3.016E-08

1 TEST CASE 2A - CALM OCEAN - TROPICAL

ATMOSPHERIC TRANSMISSION AND WEIGHTING FUNCTIONS

FREQUENCY - 18.00 GHZ ANGLE - 54.00 DEGREES

HEIGHT	PRESSURE	TRANSMISSION	TRANSMISSION	WEIGHTING FUCNTIONS	
(KM)	(TORR)	H TO SPACE	H TO GROUND	GROUND BASED	SPACE BASED
.000	759.81	1.0000E+00	8.9376E-01	2.9409E-02	4.5284E-02
.250	739.09	9.8749E-01	9.0508E-01	5.5860E-02	4.1721E-02
.500	718.93	9.7624E-01	9.1551E-01	7.9654E-02	3.8360E-02
.750	698.20	9.6612E-01	9.2510E-01	1.0104E-01	3.5165E-02
1.000	678.06	9.5703E-01	9.3389E-01	1.2025E-01	3.2175E-02
1.250	659.23	9.4885E-01	9.4193E-01	1.3753E-01	2.9412E-02
1.500	640.93	9.4150E-01	9.4929E-01	1.5307E-01	2.6843E-02
1.750	622.09	9.3490E-01	9.5600E-01	1.6702E-01	2.4431E-02
2.000	603.80	9.2896E-01	9.6211E-01	1.7955E-01	2.2202E-02
2.250	586.68	9.2363E-01	9.6766E-01	1.8828E-01	1.5619E-02
2.500	570.05	9.1992E-01	9.7156E-01	1.9379E-01	9.9266E-03
2.750	552.91	9.1758E-01	9.7404E-01	1.9889E-01	9.2349E-03
3.000	536.29	9.1541E-01	9.7635E-01	2.0361E-01	8.5858E-03
3.250	520.69	9.1340E-01	9.7850E-01	2.0784E-01	7.7233E-03
3.500	505.54	9.1160E-01	9.8043E-01	2.1163E-01	6.9466E-03
3.750	489.92	9.0999E-01	9.8217E-01	2.1502E-01	6.2358E-03
4.000	474.79	9.0855E-01	9.8372E-01	1.1054E-01	5.6022E-03
4.500	446.17	9.0597E-01	9.8653E-01	1.1298E-01	4.5228E-03
5.000	419.28	9.0389E-01	9.8879E-01	1.1492E-01	3.6089E-03
5.500	393.36	9.0225E-01	9.9059E-01	1.1649E-01	2.9438E-03
6.000	369.03	9.0091E-01	9.9206E-01	1.1777E-01	2.3968E-03
6.500	345.80	8.9982E-01	9.9326E-01	1.1875E-01	1.8488E-03
7.000	324.03	8.9898E-01	9.9419E-01	1.1952E-01	1.4567E-03
7.500	303.10	8.9833E-01	9.9491E-01	1.2017E-01	1.2123E-03
8.000	283.52	8.9778E-01	9.9552E-01	1.2071E-01	1.0222E-03
8.500	264.51	8.9732E-01	9.9603E-01	1.2116E-01	8.6078E-04
9.000	246.77	8.9693E-01	9.9646E-01	1.2156E-01	7.4871E-04
9.500	230.08	8.9659E-01	9.9684E-01	1.2191E-01	6.6018E-04
10.000	214.52	8.9630E-01	9.9717E-01	1.2222E-01	5.9111E-04
10.500	199.36	8.9603E-01	9.9746E-01	1.2250E-01	5.2334E-04
11.000	185.27	8.9580E-01	9.9772E-01	1.2275E-01	4.7208E-04
11.500	172.04	8.9559E-01	9.9796E-01	1.2298E-01	4.3291E-04

12.000	159.76	8.9539E-01	9.9818E-01	1.2318E-01	3.9697E-04
12.500	147.68	8.9521E-01	9.9837E-01	1.2338E-01	3.6354E-04
13.000	136.51	8.9505E-01	9.9856E-01	1.2355E-01	3.3297E-04
13.500	126.38	8.9490E-01	9 9872E-01	1.2371E-01	3.0586E-04
14.000	117.01	8.9476E-01	9.9888E 01	1.2386E-01	2.8104E-04
14.500	107.63	8.9464E-01	9.9902E-01	1.2399E-01	2.5368E-04
15.000	99.01	8.9452E-01	9.9914E-01	1.2411E-01	2.2900E-04
15.500	90.79	8.9442E-01	9.9926E-01	1.2422E-01	2.0711E-04
16.000	83.26	8.9433E-01	9.9936E-01	1.2432E-01	1.8738E-04
16.500	76.49	8.9425E-01	9.9946E-01	1.2441E-01	1.6400E-04
17.000	70.28	8.9417E-01	9.9954E-01	1.2448E-01	1.4348E-04
17.500	64.49	8.9411E-01	9.9961E-01	1.2455E-01	1.1980E-04
18.000	59.18	8.9405E-01	9.9967E-01	1.2460E-01	1.0001E-04
18.500	54.37	8.9401E-01	9.9972E-01	1.2464E-01	8.3664E-05
19.000	49.95	8.9397E-01	9.9976E-01	1.2468E-01	6.9980E-05
19.500	46.01	8.9394E-01	9.9980E-01	1.2471E-01	5.8790E-05
20.000	42.38	8.9391E-01	9.9982E-01	1.2474E-01	4.9387E-05
20.500	39.06	8.9389E-01	9.9985E-01	1.2476E-01	4.1538E-05
21.000	36.00	8.9387E-01	9.9987E-01	1.2478E-01	3.4935E-05
21.500	33.23	8.9386E-01	9.9989E-01	1.2479E-01	2.9459E-05
22.000	30.68	8.9385E-01	9.9990E-01	1.2481E-01	2.4841E-05
22.500	28.38	8.9383E-01	9.9991E-01	1.2482E-01	2.1308E-05
23.000	26.25	8.9382E-01	9.9993E-01	1.2483E-01	1.8275E-05
23.500	24.30	8.9382E-01	9.9993E-01	1.2483E-01	1.5694E-05
24.000	22.50	8.9381E-01	9.9994E-01	1.2484E-01	1.3475E-05
24.500	20.83	8.9380E-01	9.9995E-01	1.2485E-01	1.1562E-05
25.000	19.28	8.9380E-01	9.9996E-01	2.4975E-02	9.9191E-06
27.500	13.28	8.9378E-01	9.9998E-01	2.4977E-02	4.4006E-06
30.000	9.15	8.9377E-01	9.9999E-01	2.4978E-02	1.9498E-06
32.500	6.42	8.9376E-01	1.0000E+00	2.4979E-02	8.9645E-07
35.000	4.50	8.9376E-01	1.0000E+00	2.4979E-02	4.1281E-07
37.500	3.21	8.9376E-01	1.0000E+00	2.4979E-02	1.9677E-07
40.000	2.29	8.9376E-01	1.0000E+00	2.4979E-02	9.3929E-08
42.500	1.65	8.9376E-01	1.0000E+00	2.4979E-02	4.6044E-08
45.000	1.19	8.9376E-01	1.0000E+00	2.4979E-02	2.2600E-08
47.500	.87	8.9376E-01	1.0000E+00	2.4979E-02	1.1816E-08
50.000	.64	8.9376E-01	1.0000E+00		

1 TEST CASE 2A - CALM OCEAN - TROPICAL

FREQUENCY = 18.00 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1123E+00	.89376	30.45403	119.08481	195.90263	.25458	.57344

1 TEST CASE 2B - WET SNOWPACK - MID-LATITUDE WINTER

ATMOSPHERIC PROFILE - MID-LATITUDE WINTER MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1018.00	272.20	.7700	.0000	.000
.500	957.70	270.50	.7300	.0000	.000
1.000	897.30	268.70	.7000	.0000	.000
1.500	843.50	267.00	.6700	.0000	.000
2.000	789.70	265.20	.6500	.0000	.000
2.500	741.80	263.50	.6000	.0000	.000
3.000	693.80	261.70	.5500	.0000	.000
3.500	651.00	258.70	.5300	.0000	.000
4.000	608.10	255.70	.5000	.0000	.000
5.000	531.30	249.70	.4800	.0000	.000
6.000	462.70	243.70	.4500	.0000	.000
7.000	401.60	237.70	.4000	.0000	.000
8.000	347.30	231.70	.3500	.0000	.000
9.000	299.20	225.70	.3200	.0000	.000
10.000	256.80	219.70	.3000	.0000	.000
11.000	219.90	219.20	.0000	.0000	.000
12.000	188.20	218.70	.0000	.0000	.000
13.000	161.00	218.20	.0000	.0000	.000
14.000	137.80	217.70	.0000	.0000	.000
15.000	117.80	217.20	.0000	.0000	.000
16.000	100.70	216.70	.0000	.0000	.000
17.000	86.10	216.20	.0000	.0000	.000
18.000	73.50	215.70	.0000	.0000	.000

19.000	62.80	215.20	.0000	.0000	.000
20.000	53.70	215.20	.0000	.0000	.000
21.000	45.80	215.20	.0000	.0000	.000
22.000	39.10	215.20	.0000	.0000	.000
23.000	33.40	215.20	.0000	.0000	.000
24.000	28.60	215.20	.0000	.0000	.000
25.000	24.30	215.20	.0000	.0000	.000
30.000	11.10	217.40	.0000	.0000	.000
35.000	5.18	227.80	.0000	.0000	.000
40.000	2.53	243.20	.0000	.0000	.000
45.000	1.29	258.50	.0000	.0000	.000
50.000	.68	265.70	.0000	.0000	.000

IATM = 1 MOD = 3 MHUMID = 3 MCLOUD = 1 MRAIN = 1 TGRND = 272.20

GROUND = 4 TEMP1 = 273.00 TEMP2 = 273.00 A1 = .02000 FS1 = .05000 A2 = .04000 FS2 = .25000
E2WET = (4.00000, .10000) DEPWET = 60.000

1 TEST CASE 2B - WET SNOWPACK - MID-LATITUDE WINTER

FREQUENCY = 10.60 GHZ

TOTAL WATER VAPOR CONTENT = .801 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.2156E-01	.97867	5.42775	251.71726	269.72817	.92298	.99196

1 TEST CASE 2B - WET SNOWPACK - MID-LATITUDE WINTER

FREQUENCY = 18.00 GHZ

TOTAL WATER VAPOR CONTENT = .801 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL

0 54.0 .4075E-01 .96007 10.32906 221.80822 248.55205 .80167 .90804
1 TEST CASE 2C - VEGETATION (MV=0.1) - U.S. STANDARD

ATMOSPHERIC PROFILE = U.S. STANDARD (1962) MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	288.10	.7500	.0000	.000
.500	955.80	284.90	.7000	.0000	.000
1.000	898.60	281.60	.6500	.0000	.000
1.500	846.80	278.40	.6000	.0000	.000
2.000	795.00	275.10	.5500	.0000	.000
2.500	748.10	271.90	.5000	.0000	.000
3.000	701.20	268.70	.4500	.0000	.000
3.500	658.90	265.50	.4200	.0000	.000
4.000	616.60	262.20	.4000	.0000	.000
5.000	540.50	255.70	.3500	.0000	.000
6.000	472.20	249.20	.3000	.0000	.000
7.000	411.10	242.70	.3000	.0000	.000
8.000	356.50	236.20	.3000	.0000	.000
9.000	308.00	229.70	.2000	.0000	.000
10.000	265.00	223.20	.1000	.0000	.000
11.000	227.00	216.80	.0000	.0000	.000
12.000	194.00	216.60	.0000	.0000	.000
13.000	165.80	216.60	.0000	.0000	.000
14.000	141.70	216.60	.0000	.0000	.000
15.000	121.10	216.60	.0000	.0000	.000
16.000	103.50	216.60	.0000	.0000	.000
17.000	88.50	216.60	.0000	.0000	.000
18.000	75.65	216.60	.0000	.0000	.000
19.000	64.67	216.60	.0000	.0000	.000
20.000	55.29	216.60	.0000	.0000	.000
21.000	47.29	217.60	.0000	.0000	.000
22.000	40.47	218.60	.0000	.0000	.000
23.000	34.67	219.60	.0000	.0000	.000
24.000	29.72	220.60	.0000	.0000	.000
25.000	25.49	221.60	.0000	.0000	.000

30.000	11.97	226.50	.0000	.0000	.000
35.000	5.75	236.50	.0000	.0000	.000
40.000	2.87	253.40	.0000	.0000	.000
45.000	1.49	264.20	.0000	.0000	.000
50.000	.80	270.60	.0000	.0000	.000

IATM = 1 MOD = 6 MHUMID = 6 MCLOUD = 1 MRAIN = 1 TGRND = 288.10

GROUND = 5 TEMP1 = 288.00 TEMP2 = 286.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

1 TEST CASE 2C - VEGETATION (MV=0.1) - U.S. STANDARD

FREQUENCY = 10.60 GHZ

TOTAL WATER VAPOR CONTENT = 1.612 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.2359E-01	.97669	6.16124	266.46509	282.48119	.92342	.98159

1 TEST CASE 2C - VEGETATION (MV=0.1) - U.S. STANDARD

FREQUENCY = 18.00 GHZ

TOTAL WATER VAPOR CONTENT = 1.612 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.5975E-01	.94200	15.77279	282.94803	285.59634	.98345	.99377

1 TEST CASE 2D - WET SOIL - U.S. STANDARD

ATMOSPHERIC PROFILE - U.S. STANDARD (1962) MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	288.10	.7500	.0000	.000
.500	955.80	284.90	.7000	.0000	.000
1.000	898.60	281.60	.6500	.0000	.000
1.500	846.80	278.40	.6000	.0000	.000
2.000	795.00	275.10	.5500	.0000	.000
2.500	748.10	271.90	.5000	.0000	.000
3.000	701.20	268.70	.4500	.0000	.000
3.500	658.90	265.50	.4200	.0000	.000
4.000	616.60	262.20	.4000	.0000	.000
5.000	540.50	255.70	.3500	.0000	.000
6.000	472.20	249.20	.3000	.0000	.000
7.000	411.10	242.70	.3000	.0000	.000
8.000	356.50	236.20	.3000	.0000	.000
9.000	308.00	229.70	.2000	.0000	.000
10.000	265.00	223.20	.1000	.0000	.000
11.000	227.00	216.80	.0000	.0000	.000
12.000	194.00	216.60	.0000	.0000	.000
13.000	165.80	216.60	.0000	.0000	.000
14.000	141.70	216.60	.0000	.0000	.000
15.000	121.10	216.60	.0000	.0000	.000
16.000	103.50	216.60	.0000	.0000	.000
17.000	88.50	216.60	.0000	.0000	.000
18.000	75.65	216.60	.0000	.0000	.000
19.000	64.67	216.60	.0000	.0000	.000
20.000	55.29	216.60	.0000	.0000	.000
21.000	47.29	217.60	.0000	.0000	.000
22.000	40.47	218.60	.0000	.0000	.000
23.000	34.67	219.60	.0000	.0000	.000
24.000	29.72	220.60	.0000	.0000	.000
25.000	25.49	221.60	.0000	.0000	.000
30.000	11.97	226.50	.0000	.0000	.000
35.000	5.75	236.50	.0000	.0000	.000
40.000	2.87	253.40	.0000	.0000	.000

45.000	1.49	264.20	.0000	.0000	.000
50.000	.80	270.60	.0000	.0000	.000

IATM = 1 MOD = 6 MHUMID = 6 MCLOUD = 1 MRAIN = 1 TGRND = 288.10

GROUND = 6 TEMP1 = 288.00 TEMP2 = 288.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 50.000 H = .00000 DMV = .20000
WT = .25000 GA = .45000 PO = .50000 ROCK = (5.00000, .10000)

1 TEST CASE 2D - WET SOIL - U.S. STANDARD

FREQUENCY = 10.60 GHZ

TOTAL WATER VAPOR CONTENT = 1.612 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.2359E-01	.97669	6.16124	210.99537	280.47338	.72198	.97430

1 TEST CASE 2D - WET SOIL - U.S. STANDARD

FREQUENCY = 18.00 GHZ

TOTAL WATER VAPOR CONTENT = 1.612 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .000 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.5975E-01	.94200	15.77279	220.28406	281.49527	.73918	.97779

Table 10. Surface Properties Output for Surface Model Test Case 2

1

GROUND = 0 TEMP1 = 300.00

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL	SURFACE PARAMETERS E2	EM	DEL
10.60	54.0	.24322	.55446	(.00000, .00000)	(.00000, .00000)	.00000
18.00	54.0	.25458	.57344	(.00000, .00000)	(.00000, .00000)	.00000

GROUND = 4 TEMP1 = 273.00 TEMP2 = 273.00 A1 = .02000 FS1 = .05000 A2 = .04000 FS2 = .25000
E2WET = (4.00000, .10000) DEPWET = 60.000

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL	SURFACE PARAMETERS E2	EM	DEL
10.60	54.0	.92298	.99196	(4.00000, .10000)	(.00000, .00000)	.00000
18.00	54.0	.80167	.90804	(4.00000, .10000)	(.00000, .00000)	.00000

GROUND = 5 TEMP1 = 286.00 TEMP2 = 286.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL	SURFACE PARAMETERS E2	EM	DEL
10.60	54.0	.92342	.98159	(7.03494, 2.73882)	(1.00357, .00112)	.00420
18.00	54.0	.98345	.99377	(5.62572, 2.70754)	(1.00300, .00129)	.00320

GROUND = 6 TEMP1 = 288.00 TEMP2 = 288.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 50.000 H = .00000 DMV = .20000
WT = .25000 GA = .45000 PO = .50000 ROCK = (5.00000, .10000)

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL	SURFACE PARAMETERS E2	EM	DEL
10.60	54.0	.72198	.97430	(7.15297, 2.67102)	(4.13184, .70205)	.84066
18.00	54.0	.73918	.97779	(5.75955, 2.72012)	(3.78349, .71433)	.69469

Table 11. Tabular Output for Surface Model Test Case 2

1

0 TEST CASE 2A - CALM OCEAN - TROPICAL

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 1 MRAIN = 1 TGRND = 300.00 ATMOSPHERIC PROFILE = TROPICAL MODEL

GROUND = 0 TEMP1 = 300.00

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
10.60	54.0	.96979	8.43452	85.39591	173.40154	.24322	.55446
18.00	54.0	.89376	30.45403	119.08481	195.90263	.25458	.57344

0 TEST CASE 2B - WET SNOWPACK - MID-LATITUDE WINTER

IATM = 1 MOD = 3 MHUMID = 3 MCLOUD = 1 MRAIN = 1 TGRND = 272.20 ATMOSPHERIC PROFILE = MID-LATITUDE WINTER MODEL

GROUND = 4 TEMP1 = 273.00 TEMP2 = 273.00 A1 = .02000 FS1 = .05000 A2 = .04000 FS2 = .25000
E2WET = (4.00000, .10000) DEPWET = 60.000

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
10.60	54.0	.97867	5.42775	251.71726	269.72817	.92298	.99196
18.00	54.0	.96007	10.32906	221.80822	248.55205	.80167	.90804

0 TEST CASE 2C - VEGETATION (MV=0.1) - U.S. STANDARD

IATM = 1 MOD = 6 MHUMID = 6 MCLOUD = 1 MRAIN = 1 TGRND = 288.10 ATMOSPHERIC PROFILE = U.S. STANDARD (1962) MODEL

GROUND = 5 TEMP1 = 286.00 TEMP2 = 286.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
10.60	54.0	.97669	6.16124	266.46509	282.48119	.92342	.98159
18.00	54.0	.94200	15.77279	282.94803	285.59634	.98345	.99377

0 TEST CASE 2D - WET SOIL - U.S. STANDARD

IATM = 1 MOD = 6 MHUMID = 6 MCLOUD = 1 MRAIN = 1 TGRND = 288.10 ATMOSPHERIC PROFILE = U.S. STANDARD (1962) MODEL

GROUND = 6 TEMP1 = 288.00 TEMP2 = 288.00 LP = .10000 LZ = 1.00000 MV = .10000 E2RAN = (.00000, .00000)
DEPRAN = 50.000 H = .00000 DMV = .20000
WT = .25000 GA = .45000 PO = .50000 ROCK = (5.00000, .10000)

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K)			EMISSIVITY	
			DOWN	UP HORIZ	UP VERT	HORIZONTAL	VERTICAL
10.60	54.0	.97669	6.16124	210.99537	280.47338	.72198	.97430
18.00	54.0	.94200	15.77279	220.28406	281.49527	.73918	.97779

Table 12. Input for Multiple Scattering Test Case 3

```
 TEST CASE 3A - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - NO MS
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 3 RN 3
GRN 5 ET 1   300.0     298.0
  0.0                   0.5                                              -1.
  0.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 37.00        0.000     0.000
 -1.         -1.        -1.
RPT 1
 TEST CASE 3B - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - MS
RAD 1 AT 1 SF 1 MS 1 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 3 RN 3
GRN 5 ET 1   300.0     298.0
  0.0                   0.5                                              -1.
  0.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 37.00        0.000     0.000
 -1.         -1.        -1.
RPT 1
 TEST CASE 3C - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - NO MS
RAD 1 AT 1 SF 1 MS 0 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 3 RN 5
GRN 5 ET 1   300.0     298.0
  0.0                   0.5                                              -1.
  0.0
 54.00   10.0C   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 37.00        0.000     0.000
 -1.         -1.        -1.
RPT 1
 TEST CASE 3D - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - MS
RAD 1 AT 1 SF 1 MS 1 PL 0 AN 1 MD 1 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 3 RN 5
GRN 5 ET 1   300.0     298.0
  0.0                   0.5                                              -1.
  0.0
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
 37.00        0.000     0.000
 -1.         -1.        -1.
RPT 0
```

Table 13. Output for Multiple Scattering Test Case 3

1 TEST CASE 3A - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - NO MS

ATMOSPHERIC PROFILE = TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	5.000
.500	958.50	297.00	.7500	.0000	4.500
1.000	904.00	294.00	.7500	.3500	4.200
1.500	854.50	291.00	.7500	1.0000	4.000
2.000	805.00	288.00	.7500	1.0000	3.800
2.500	760.00	286.00	.3500	1.0000	3.400
3.000	715.00	284.00	.3500	1.0000	2.800
3.500	674.00	280.50	.3500	1.0000	2.300
4.000	633.00	277.00	.3500	.8000	1.800
5.000	559.00	270.00	.3500	.5000	.900
6.000	492.00	264.00	.3500	.3000	.000
7.000	432.00	257.00	.3000	.2000	.000
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000
12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000
30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000

40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

```
IATM = 1  MOD = 1  MHUMID = 1  MCLOUD = 3  MRAIN = 3  TGRND = 300.00

GROUND = 5  TEMP1 = 300.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
            DEPRAN = 200.000  H =  .10000  DMV =  .20000
            VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)
1WATER-VAPOR ROTATIONAL SPECTRAL LINE PARAMETERS          NLINES=   54
```

DESIGNATION	FREQ,GHZ	PARITY	STRENGTH	TERM1	TERM2	WDAIR	WDH2O	TEXP
5,23-6,16	22.23520	EOOE	.0549	446.39	447.17	.09019	.47770	.626
2,20-3,13	183.31010	EEOO	.1015	136.15	142.30	.09600	.49370	.649
9,36-10,29	323.15850	OEEO	.0870	1283.02	1293.80	.07652	.40120	.420
4,22-5,15	323.75810	EEOO	.0891	315.70	326.50	.09292	.50710	.619
3,21-4,14	377.41800	EOOE	.1224	212.12	224.71	.09480	.52800	.630
11,210-10,37	389.70880	EEOO	.0680	1525.31	1538.31	.07020	.38070	.330
6,60-7,53	435.87430	EEOO	.0820	1045.14	1059.68	.05000	.26480	.290
5,50-6,43	437.67300	OEEO	.0987	742.18	756.78	.05900	.34800	.360
6,61-7,52	441.57000	EOOE	.0820	1045.14	1059.87	.05023	.27090	.332
3,30-4,23	445.76690	OEEO	.1316	285.46	300.33	.08247	.47480	.510
5,51-6,42	465.85190	OOEE	.0990	742.18	757.72	.06290	.35210	.380
4,40-5,33	470.94810	EEOO	.1165	488.19	503.90	.06900	.39870	.380
7,17-6,24	487.13600	OOEE	.0330	586.46	602.71	.08610	.49260	.510
7,70-8,63	498.52750	OEEO	.0770	1394.96	1411.59	.04240	.20510	.320
7,71-8,62	498.52750	OOEE	.0720	1394.96	1411.59	.04240	.20500	.340
1,01-1,10	557.58340	EOOE	1.5000	23.76	42.36	.11115	.48890	.645
4,41-5,32	617.83830	EOOE	.1193	488.19	508.80	.07606	.42620	.600
8,80-9,73	641.52060	EEOO	.0660	1789.36	1810.76	.03800	.17200	.400
8,81-9,72	641.52060	EOOE	.0660	1789.36	1810.76	.03800	.17150	.400
2,02-2,11	752.73750	EEOO	2.0739	70.08	95.19	.10440	.46480	.690
8,35-9,28	833.07750	OOEE	.1570	1052.72	1080.51	.07980	.42970	.510
11,29-10,56	857.95890	EOOE	.0670	1690.74	1719.36	.05500	.30900	.200
9,90-10,83	859.15800	OEEO	.0590	2225.87	2254.53	.03570	.15350	.480
9,91-10,82	859.15800	OOEE	.0590	2225.87	2254.53	.03570	.15350	.480
3,31-4,22	912.51810	OOEE	.1613	285.26	315.70	.08638	.46890	.676
4,31-5,24	961.38160	OOEE	.2622	383.93	416.00	.08262	.47220	.560
1,11-2,02	987.46210	OOEE	.7557	37.14	70.08	.10316	.50690	.660
12,211-11,38	1077.39490	EOOE	.0420	1774.85	1810.79	.06100	.34760	.250

3,03-3,12	1098.37930	EOOE	2.1809	136.74	173.38	.09944	.55900	.701
10,29-9,55	1107.67230	EEOO	.0500	1438.19	1475.14	.06100	.63100	.250
0,00-1,11	1113.36810	EEOO	1.0000	.00	37.14	.10034	.50260	.689
10,100-11,93	1142.74610	EEOO	.0540	2702.61	2740.73	.03434	.12970	.503
10,101-11,92	1142.74610	EOOE	.0540	2702.61	2740.73	.03434	.12970	.503
8,18-7,25	1145.74390	OEEO	.0250	744.20	782.42	.08008	.45630	.498
2,21-3,32	1154.13760	EOOE	.3003	134.88	173.38	.09515	.54850	.610
5,41-6,34	1159.83330	EOOE	.2784	610.34	649.03	.07131	.42290	.399
3,12-3,21	1161.33220	OEEO	2.5434	173.38	212.12	.09487	.50600	.682
7,61-8,54	1163.43070	EOOE	.2230	1216.38	1255.19	.05160	.29080	.290
6,51-7,44	1169.72600	OOEE	.2520	888.74	927.76	.06480	.37400	.360
7,62-8,53	1187.11300	EEOO	.2230	1216.38	1255.98	.05420	.30610	.300
8,71-9,64	1208.99660	OOEE	.1990	1591.11	1631.44	.04450	.23810	.320
8,72-9,63	1213.19350	OEEO	.1990	1591.11	1631.58	.04470	.24110	.340
4,13-4,22	1213.19350	OOEE	3.6547	272.23	315.70	.09507	.50910	.720
2,11-2,20	1227.88250	OOEE	1.2594	95.19	136.15	.09792	.46580	.670
6,52-7,43	1227.94510	OEEO	.2530	888.70	931.33	.06880	.26820	.450
7,34-8,27	1294.43280	OEEO	.1840	842.51	885.69	.08190	.45770	.550
9,18-8,45	1309.72130	OEEO	.0470	1079.20	1122.89	.06000	.34800	.250
5,32-6,25	1323.21130	OEEO	.3117	508.80	552.94	.08313	.49390	.571
9,81-10,74	1329.80630	EOOE	.1730	2010.19	2054.55	.03900	.20770	.390
9,82-10,73	1329.80630	EEOO	.1730	2010.19	2054.55	.03900	.20770	.390
8,17-7,44	1342.69670	OOEE	.0360	882.97	927.76	.06600	.37500	.300
5,14-5,23	1407.44830	OEEO	4.2239	399.44	446.39	.09470	.51230	.722
10,19-9,46	1423.33640	OOEE	.0590	1293.22	1340.70	.05500	.32200	.240
6,33-7,26	1435.92700	OOEE	.2580	661.54	709.44	.08300	.46420	.590

1 TEST CASE 3A - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - NO MS

FREQUENCY = 37.00 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.3949E+01	.01927	266.17311	292.27456	292.27211	.95835	.95461

1 TEST CASE 3B - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - MS

ATMOSPHERIC PROFILE - TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	5.000
.500	958.50	297.00	.7500	.0000	4.500
1.000	904.00	294.00	.7500	.3500	4.200
1.500	854.50	291.00	.7500	1.0000	4.000
2.000	805.00	288.00	.7500	1.0000	3.800
2.500	760.00	286.00	.3500	1.0000	3.400
3.000	715.00	284.00	.3500	1.0000	2.800
3.500	674.00	280.50	.3500	1.0000	2.300
4.000	633.00	277.00	.3500	.8000	1.800
5.000	559.00	270.00	.3500	.5000	.900
6.000	492.00	264.00	.3500	.3000	.000
7.000	432.00	257.00	.3000	.2000	.000
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000
12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000
30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000
40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 3 MRAIN = 3 TGRND = 300.00

GROUND = 5 TEMP1 = 300.00 TEMP2 = 298.00 LP = .10000 LZ = 1.00000 MV = .50000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

1 TEST CASE 3B - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - MS

FREQUENCY = 37.00 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	MS BRIGHTNESS TEMPERATURE UP HORIZ	MS BRIGHTNESS TEMPERATURE UP VERT	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL
0	54.0	.3949E+01	.01927	276.88100	277.91067	.95835	.95461

1 TEST CASE 3C - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - NO MS

ATMOSPHERIC PROFILE = TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	15.000
.500	958.50	297.00	.7500	.0000	14.200
1.000	904.00	294.00	.7500	.3500	13.500
1.500	854.50	291.00	.7500	1.0000	12.600
2.000	805.00	288.00	.7500	1.0000	11.700
2.500	760.00	286.00	.3500	1.0000	10.100
3.000	715.00	284.00	.3500	1.0000	8.600
3.500	674.00	280.50	.3500	1.0000	6.900
4.000	633.00	277.00	.3500	.8000	5.300
5.000	559.00	270.00	.3500	.5000	2.600
6.000	492.00	264.00	.3500	.3000	1.000
7.000	432.00	257.00	.3000	.2000	.200
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000

12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000
30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000
40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 3 MRAIN = 5 TGRND = 300.00

GROUND = 5 TEMP1 = 300.00 TEMP2 = 298.00 LP = .10000 LZ = 1.00000 MV = .50000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

1 TEST CASE 3C - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - NO MS

FREQUENCY = 37.00 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.8297E+01	.00025	267.87295	296.54090	296.54087	.95835	.95461

1 TEST CASE 3D - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - MS

ATMOSPHERIC PROFILE - TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	15.000
.500	958.50	297.00	.7500	.0000	14.200
1.000	904.00	294.00	.7500	.3500	13.500
1.500	854.50	291.00	.7500	1.0000	12.600
2.000	805.00	288.00	.7500	1.0000	11.700
2.500	760.00	286.00	.3500	1.0000	10.100
3.000	715.00	284.00	.3500	1.0000	8.600
3.500	674.00	280.50	.3500	1.0000	6.900
4.000	633.00	277.00	.3500	.8000	5.300
5.000	559.00	270.00	.3500	.5000	2.600
6.000	492.00	264.00	.3500	.3000	1.000
7.000	432.00	257.00	.3000	.2000	.200
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000
12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000
30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000
40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

```
IATM = 1  MOD = 1  MHUMID = 1  MCLOUD = 3  MRAIN = 5  TGRND = 300.00

GROUND = 5  TEMP1 = 300.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
            DEPRAN = 200.000  H =  .10000  DMV =  .20000
            VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)
1 TEST CASE 3D - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - MS

          FREQUENCY =    37.00 GHZ

          TOTAL WATER VAPOR CONTENT =    3.969 PRECIPITABLE CM

          TOTAL CLOUD WATER CONTENT =     .428 GRAMS PER SQ CM
```

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	MS BRIGHTNESS TEMPERATURE UP HORIZ	MS BRIGHTNESS TEMPERATURE UP VERT	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL
0	54.0	.8297E+01	.00025	266.77108	268.04034	.95835	.95461

Table 14. Surface Properties Output for Multiple Scattering Test Case 3

```
1

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

  FREQUENCY     NADIR ANGLE        EMISSIVITY          ---------------- SURFACE PARAMETERS ----------------
    (GHZ)          (DEG)      HORIZONTAL    VERTICAL              E2                      EM                 DEL

    37.00          54.0         .95835       .95461     ( 4.73474, 2.20447)    ( 1.02382,  .02573)      .35412

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

  FREQUENCY     NADIR ANGLE        EMISSIVITY          ---------------- SURFACE PARAMETERS ----------------
    (GHZ)          (DEG)      HORIZONTAL    VERTICAL              E2                      EM                 DEL

    37.00          54.0         .95835       .95461     ( 4.73474, 2.20447)    ( 1.02382,  .02573)      .35412

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

  FREQUENCY     NADIR ANGLE        EMISSIVITY          ---------------- SURFACE PARAMETERS ----------------
    (GHZ)          (DEG)      HORIZONTAL    VERTICAL              E2                      EM                 DEL

    37.00          54.0         .95835       .95461     ( 4.73474, 2.20447)    ( 1.02382,  .02573)      .35412

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

  FREQUENCY     NADIR ANGLE        EMISSIVITY          ---------------- SURFACE PARAMETERS ----------------
    (GHZ)          (DEG)      HORIZONTAL    VERTICAL              E2                      EM                 DEL

    37.00          54.0         .95835       .95461     ( 4.73474, 2.20447)    ( 1.02382,  .02573)      .35412
```

Table 15. Tabular Output for Multiple Scattering Test Case 3

```
1

0 TEST CASE 3A - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - NO MS

 IATM = 1  MOD = 1  MHUMID = 1  MCLOUD = 3  MRAIN = 3  TGRND = 300.00  ATMOSPHERIC PROFILE =   TROPICAL MODEL

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

   FREQUENCY    NADIR ANGLE   TRANSMISSION     BRIGHTNESS TEMPERATURE (DEGREES K)            EMISSIVITY
     (GHZ)         (DEG)         FACTOR        DOWN        UP HORIZ      UP VERT       HORIZONTAL    VERTICAL

     37.00         54.0         .01927      266.17311    292.27456     292.27211       .95835       .95461
0 TEST CASE 3B - VEGETATION (MV=0.5) - TROPICAL - LIGHT RAIN - MS

 IATM = 1  MOD = 1  MHUMID = 1  MCLOUD = 3  MRAIN = 3  TGRND = 300.00  ATMOSPHERIC PROFILE =   TROPICAL MODEL

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

   FREQUENCY    NADIR ANGLE   TRANSMISSION  MS BRIGHTNESS TEMPERATURE         EMISSIVITY
     (GHZ)         (DEG)         FACTOR       UP HORIZ      UP VERT     HORIZONTAL    VERTICAL

     37.00         54.0         .01927      276.88100    277.91067      .95835       .95461
0 TEST CASE 3C - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - NO MS

 IATM = 1  MOD = 1  MHUMID = 1  MCLOUD = 3  MRAIN = 5  TGRND = 300.00  ATMOSPHERIC PROFILE =   TROPICAL MODEL

 GROUND = 5  TEMP1 = 298.00  TEMP2 = 298.00  LP =  .10000  LZ = 1.00000  MV =  .50000  E2RAN = (  .00000,  .00000)
             DEPRAN = 200.000  H =  .10000  DMV =  .20000
             VV =  .00330  VB =  .10000  VBW =  .05000  BULK = (  3.000000,   .000000)

   FREQUENCY    NADIR ANGLE   TRANSMISSION     BRIGHTNESS TEMPERATURE (DEGREES K)            EMISSIVITY
     (GHZ)         (DEG)         FACTOR        DOWN        UP HORIZ      UP VERT       HORIZONTAL    VERTICAL

     37.00         54.0         .00025      267.87295    296.54090     296.54087       .95835       .95461
```

0 TEST CASE 3D - VEGETATION (MV=0.5) - TROPICAL - SUMMER CUMULUS RAIN - MS

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 3 MRAIN = 5 TGRND = 300.00 ATMOSPHERIC PROFILE = TROPICAL MODEL

GROUND = 5 TEMP1 = 298.00 TEMP2 = 298.00 LP = .10000 LZ = 1.00000 MV = .50000 E2RAN = (.00000, .00000)
DEPRAN = 200.000 H = .10000 DMV = .20000
VV = .00330 VB = .10000 VBW = .05000 BULK = (3.000000, .000000)

FREQUENCY (GHZ)	NADIR ANGLE (DEG)	TRANSMISSION FACTOR	MS BRIGHTNESS TEMPERATURE UP HORIZ	MS BRIGHTNESS TEMPERATURE UP VERT	EMISSIVITY HORIZONTAL	EMISSIVITY VERTICAL
37.00	54.0	.00025	266.77108	268.04034	.95835	.95461

Table 16. Input for Spectral Test Case 4

```
 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.
RAD 1 AT 1 SF 3 MS 0 PL 0 AN 1 MD 0 TB 1 AP 0 AI 1 WF 0 WI 1 WL 0 PR 0  300.00
MOD 1 RH 1 CL 3 RN 3
  1.00
  1.00
 54.00   10.00   20.00   30.00   40.00   50.00   60.00   70.00   80.00   90.00
182.00     184.00      0.100
RPT 0
```

Table 17. Output for Spectral Test Case 4

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

ATMOSPHERIC PROFILE = TROPICAL MODEL

HEIGHT (KM)	PRESSURE (MB)	TEMPERATURE (DEG K)	RELATIVE HUMIDITY	CLOUD CONTENT (GM/CU M)	RAIN RATE (MM/HR)
.000	1013.00	300.00	.7500	.0000	5.000
.500	958.50	297.00	.7500	.0000	4.500
1.000	904.00	294.00	.7500	.3500	4.200
1.500	854.50	291.00	.7500	1.0000	4.000
2.000	805.00	288.00	.7500	1.0000	3.800
2.500	760.00	286.00	.3500	1.0000	3.400
3.000	715.00	284.00	.3500	1.0000	2.800
3.500	674.00	280.50	.3500	1.0000	2.300
4.000	633.00	277.00	.3500	.8000	1.800
5.000	559.00	270.00	.3500	.5000	.900
6.000	492.00	264.00	.3500	.3000	.000
7.000	432.00	257.00	.3000	.2000	.000
8.000	378.00	250.00	.3000	.0000	.000
9.000	329.00	244.00	.2500	.0000	.000
10.000	286.00	237.00	.2000	.0000	.000
11.000	247.00	230.00	.0000	.0000	.000
12.000	213.00	224.00	.0000	.0000	.000
13.000	182.00	217.00	.0000	.0000	.000
14.000	156.00	210.00	.0000	.0000	.000
15.000	132.00	204.00	.0000	.0000	.000
16.000	111.00	197.00	.0000	.0000	.000
17.000	93.70	195.00	.0000	.0000	.000
18.000	78.90	199.00	.0000	.0000	.000
19.000	66.60	203.00	.0000	.0000	.000
20.000	56.50	207.00	.0000	.0000	.000
21.000	48.00	211.00	.0000	.0000	.000
22.000	40.90	215.00	.0000	.0000	.000
23.000	35.00	217.00	.0000	.0000	.000
24.000	30.00	219.00	.0000	.0000	.000
25.000	25.70	221.00	.0000	.0000	.000
30.000	12.20	232.00	.0000	.0000	.000
35.000	6.00	243.00	.0000	.0000	.000

40.000	3.05	254.00	.0000	.0000	.000
45.000	1.59	265.00	.0000	.0000	.000
50.000	.85	270.00	.0000	.0000	.000

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 3 MRAIN = 3 TGRND = 300.00

1WATER-VAPOR ROTATIONAL SPECTRAL LINE PARAMETERS NLINES= 54

DESIGNATION	FREQ,GHZ	PARITY	STRENGTH	TERM1	TERM2	WDAIR	WDH2O	TEXP
5,23-6,16	22.23520	EOOE	.0549	446.39	447.17	.09019	.47770	.626
2,20-3,13	183.31010	EEOO	.1015	136.15	142.30	.09600	.49370	.649
9,36-10,29	323.15850	OEEO	.0870	1283.02	1293.80	.07652	.40120	.420
4,22-5,15	323.75810	EEOO	.0891	315.70	326.50	.09292	.50710	.619
3,21-4,14	377.41800	EOOE	.1224	212.12	224.71	.09480	.52800	.630
11,210-10,37	389.70880	EEOO	.0680	1525.31	1538.31	.07020	.38070	.330
6,60-7,53	435.87430	EEOO	.0820	1045.14	1059.68	.05000	.26480	.290
5,50-6,43	437.67300	OEEO	.0987	742.18	756.78	.05900	.34800	.360
6,61-7,52	441.57000	EOOE	.0820	1045.14	1059.87	.05023	.27090	.332
3,30-4,23	445.76690	OEEO	.1316	285.46	300.33	.08247	.47480	.510
5,51-6,42	465.85190	OOEE	.0990	742.18	757.72	.06290	.35210	.380
4,40-5,33	470.94810	EEOO	.1165	488.19	503.90	.06900	.39870	.380
7,17-6,24	487.13600	OOEE	.0330	586.46	602.71	.08610	.49260	.510
7,70-8,63	498.52750	OEEO	.0770	1394.96	1411.59	.04240	.20510	.320
7,71-8,62	498.52750	OOEE	.0720	1394.96	1411.59	.04240	.20500	.340
1,01-1,10	557.58340	EOOE	1.5000	23.76	42.36	.11115	.48890	.645
4,41-5,32	617.83830	EOOE	.1193	488.19	508.80	.07606	.42620	.600
8,80-9,73	641.52060	EEOO	.0660	1789.36	1810.76	.03800	.17200	.400
8,81-9,72	641.52060	EOOE	.0660	1789.36	1810.76	.03800	.17150	.400
2,02-2,11	752.73750	EEOO	2.0739	70.08	95.19	.10440	.46480	.690
8,35-9,28	833.07750	OOEE	.1570	1052.72	1080.51	.07980	.42970	.510
11,29-10,56	857.95890	EOOE	.0670	1690.74	1719.36	.05500	.30900	.200
9,90-10,83	859.15800	OEEO	.0590	2225.87	2254.53	.03570	.15350	.480
9,91-10,82	859.15800	OOEE	.0590	2225.87	2254.53	.03570	.15350	.480
3,31-4,22	912.51810	OOEE	.1613	285.26	315.70	.08638	.46890	.676
4,31-5,24	961.38160	OOEE	.2622	383.93	416.00	.08262	.47220	.560
1,11-2,02	987.46210	OOEE	.7557	37.14	70.08	.10316	.50690	.660
12,211-11,38	1077.39490	EOOE	.0420	1774.85	1810.79	.06100	.34760	.250
3,03-3,12	1098.37930	EOOE	2.1809	136.74	173.38	.09944	.55900	.701
10,29-9,55	1107.67230	EEOO	.0500	1438.19	1475.14	.06100	.63100	.250
0,00-1,11	1113.36810	EEOO	1.0000	.00	37.14	.10034	.50260	.689
10,100-11,93	1142.74610	EEOO	.0540	2702.61	2740.73	.03434	.12970	.503

10,101-11,92	1142.74610	EOOE	.0540	2702.61	2740.73	.03434	.12970	.503
8,18-7,25	1145.74390	OEEO	.0250	744.20	782.42	.08008	.45630	.498
2,21-3,32	1154.13760	EOOE	.3003	134.88	173.38	.09515	.54850	.610
5,41-6,34	1159.83330	EOOE	.2784	610.34	649.03	.07131	.42290	.399
3,12-3,21	1161.33220	OEEO	2.5434	173.38	212.12	.09487	.50600	.682
7,61-8,54	1163.43070	EOOE	.2230	1216.38	1255.19	.05160	.29080	.290
6,51-7,44	1169.72600	OOEE	.2520	888.74	927.76	.06480	.37400	.360
7,62-8,53	1187.11300	EEOO	.2230	1216.38	1255.98	.05420	.30610	.300
8,71-9,64	1208.99660	OOEE	.1990	1591.11	1631.44	.04450	.23810	.320
8,72-9,63	1213.19350	OEEO	.1990	1591.11	1631.58	.04470	.24110	.340
4,13-4,22	1213.19350	OOEE	3.6547	272.23	315.70	.09507	.50910	.720
2,11-2,20	1227.88250	OOEE	1.2594	95.19	136.15	.09792	.46580	.670
6,52-7,43	1227.94510	OEEO	.2530	888.70	931.33	.06880	.26820	.450
7,34-8,27	1294.43280	OEEO	.1840	842.51	885.69	.08190	.45770	.550
9,18-8,45	1309.72130	OEEO	.0470	1079.20	1122.89	.06000	.34800	.250
5,32-6,25	1323.21130	OEEO	.3117	508.80	552.94	.08313	.49390	.571
9,81-10,74	1329.80630	EOOE	.1730	2010.19	2054.55	.03900	.20770	.390
9,82-10,73	1329.80630	EEOO	.1730	2010.19	2054.55	.03900	.20770	.390
8,17-7,44	1342.69670	OOEE	.0360	882.97	927.76	.06600	.37500	.300
5,14-5,23	1407.44830	OEEO	4.2239	399.44	446.39	.09470	.51230	.722
10,19-9,46	1423.33640	OOEE	.0590	1293.22	1340.70	.05500	.32200	.240
6,33-7,26	1435.92700	OOEE	.2580	661.54	709.44	.08300	.46420	.590

V1 = 182.00000 V2 = 184.00000 DV = .10000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.00 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.8740E+02	.00000	250.01311	298.49999	298.49999	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.10 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.8973E+02	.00000	249.47183	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS-1.

FREQUENCY - 182.20 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.9207E+02	.00000	248.91201	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS-1.

FREQUENCY - 182.30 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.9440E+02	.00000	248.33742	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS-1.

FREQUENCY - 182.40 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.9668E+02	.00000	247.75339	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.50 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE	ATTENUATION	TRANSMISSION	BRIGHTNESS TEMPERATURE (DEGREES K)			EMISSIVITY	
	(DEG)	(NEPERS)	FACTOR	DOWN	UP HORIZ	UP VERT	HORIZONTAL	VERTICAL
0	54.0	.9890E+02	.00000	247.16714	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.60 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE	ATTENUATION	TRANSMISSION	BRIGHTNESS TEMPERATURE (DEGREES K)			EMISSIVITY	
	(DEG)	(NEPERS)	FACTOR	DOWN	UP HORIZ	UP VERT	HORIZONTAL	VERTICAL
0	54.0	.1010E+03	.00000	246.58820	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.70 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE	ATTENUATION	TRANSMISSION	BRIGHTNESS TEMPERATURE (DEGREES K)			EMISSIVITY	
	(DEG)	(NEPERS)	FACTOR	DOWN	UP HORIZ	UP VERT	HORIZONTAL	VERTICAL
0	54.0	.1030E+03	.00000	246.02870	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 182.80 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1048E+03	.00000	245.50355	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY - 182.90 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1064E+03	.00000	245.03025	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY - 183.00 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1077E+03	.00000	244.62816	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY - 183.10 GHZ

TOTAL WATER VAPOR CONTENT - 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT - .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1087E+03	.00000	244.31690	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.20 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1094E+03	.00000	244.11398	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.30 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1097E+03	.00000	244.03192	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.40 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1096E+03	.00000	244.07579	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.50 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1092E+03	.00000	244.24215	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.60 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1085E+03	.00000	244.51975	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.70 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1074E+03	.00000	244.89185	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

FREQUENCY = 183.80 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1061E+03	.00000	245.33909	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS-1.

FREQUENCY = 183.90 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1045E+03	.00000	245.84197	298.50000	298.50000	1.00000	1.00000

1 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS-1.

FREQUENCY = 184.00 GHZ

TOTAL WATER VAPOR CONTENT = 3.969 PRECIPITABLE CM

TOTAL CLOUD WATER CONTENT = .428 GRAMS PER SQ CM

	NADIR ANGLE (DEG)	ATTENUATION (NEPERS)	TRANSMISSION FACTOR	BRIGHTNESS TEMPERATURE (DEGREES K) DOWN	UP HORIZ	UP VERT	EMISSIVITY HORIZONTAL	VERTICAL
0	54.0	.1027E+03	.00000	246.38263	298.50000	298.50000	1.00000	1.00000

Table 18. Tabular Output for Spectral Test Case 4
1

0 TEST CASE 4 - SPECTRAL RANGE - TROPICAL - EMIS=1.

IATM = 1 MOD = 1 MHUMID = 1 MCLOUD = 3 MRAIN = 3 TGRND = 300.00 ATMOSPHERIC PROFILE = TROPICAL MODEL

FREQUENCY	NADIR ANGLE	TRANSMISSION	BRIGHTNESS TEMPERATURE (DEGREES K)			EMISSIVITY	
(GHZ)	(DEG)	FACTOR	DOWN	UP HORIZ	UP VERT	HORIZONTAL	VERTICAL
182.00	54.0	.00000	250.01311	298.49999	298.49999	1.00000	1.00000
182.10	54.0	.00000	249.47183	298.50000	298.50000	1.00000	1.00000
182.20	54.0	.00000	248.91201	298.50000	298.50000	1.00000	1.00000
182.30	54.0	.00000	248.33742	298.50000	298.50000	1.00000	1.00000
182.40	54.0	.00000	247.75339	298.50000	298.50000	1.00000	1.00000
182.50	54.0	.00000	247.16714	298.50000	298.50000	1.00000	1.00000
182.60	54.0	.00000	246.58820	298.50000	298.50000	1.00000	1.00000
182.70	54.0	.00000	246.02870	298.50000	298.50000	1.00000	1.00000
182.80	54.0	.00000	245.50355	298.50000	298.50000	1.00000	1.00000
182.90	54.0	.00000	245.03025	298.50000	298.50000	1.00000	1.00000
183.00	54.0	.00000	244.62816	298.50000	298.50000	1.00000	1.00000
183.10	54.0	.00000	244.31690	298.50000	298.50000	1.00000	1.00000
183.20	54.0	.00000	244.11398	298.50000	298.50000	1.00000	1.00000
183.30	54.0	.00000	244.03192	298.50000	298.50000	1.00000	1.00000
183.40	54.0	.00000	244.07579	298.50000	298.50000	1.00000	1.00000
183.50	54.0	.00000	244.24215	298.50000	298.50000	1.00000	1.00000
183.60	54.0	.00000	244.51975	298.50000	298.50000	1.00000	1.00000
183.70	54.0	.00000	244.89185	298.50000	298.50000	1.00000	1.00000
183.80	54.0	.00000	245.33909	298.50000	298.50000	1.00000	1.00000
183.90	54.0	.00000	245.84197	298.50000	298.50000	1.00000	1.00000
184.00	54.0	.00000	246.38263	298.50000	298.50000	1.00000	1.00000

Table 19. Attenuation Output for Spectral Test Case 4

1 FREQUENCY	TOTAL ATTENUATION FOR EACH SPECIES				
(GHZ)	OXYGEN	H2O VAPOR	CLOUD	RAIN	TOTAL
182.0000	.2441	277.1066	62.2620	39.9582	379.5709
182.1000	.2440	287.2229	62.2865	39.9614	389.7149
182.2000	.2440	297.3639	62.3110	39.9646	399.8834
182.3000	.2439	307.4383	62.3354	39.9679	409.9855
182.4000	.2438	317.3384	62.3598	39.9711	419.9131
182.5000	.2437	326.9385	62.3842	39.9743	429.5407
182.6000	.2436	336.0951	62.4086	39.9775	438.7248
182.7000	.2436	344.6479	62.4330	39.9807	447.3052
182.8000	.2435	352.4231	62.4573	39.9839	455.1078
182.9000	.2434	359.2382	62.4816	39.9871	461.9503
183.0000	.2433	364.9115	62.5059	39.9903	467.6511
183.1000	.2432	369.2741	62.5302	39.9935	472.0411
183.2000	.2432	372.1849	62.5545	39.9966	474.9792
183.3000	.2431	373.5461	62.5787	39.9998	476.3677
183.4000	.2430	373.3158	62.6029	40.0030	476.1647
183.5000	.2429	371.5136	62.6271	40.0061	474.3898
183.6000	.2429	368.2169	62.6513	40.0093	471.1204
183.7000	.2428	363.5510	62.6755	40.0124	466.4817
183.8000	.2427	357.6732	62.6996	40.0155	460.6311
183.9000	.2426	350.7583	62.7238	40.0187	453.7434
184.0000	.2426	342.9855	62.7479	40.0218	445.9977

6. SUMMARY AND RECOMMENDATIONS

6.1 Summary

This report summarizes enhancements to the RADTRAN transmittance/ brightness temperature computer code including the capabilities to: (a) evaluate frequency dependent, polarized surface emissivity - a menu driven, user selected surface type solution has been implemented based on the surface emissivity submodels described in Section 4.2. The surface emissivity supports evaluation of surface emitted brightness temperatures; (b) calculate scattering properties of precipitation - The subprogram for calculating precipitation optical properties described in Section 4.3 has been incorporated. This provides the user with frequency dependent values of extinction coefficient, single scattering albedo, asymmetry factor, and the angular scattering function for liquid and glaciated precipitation. These quantities are essential to performing the scalar multiple scattering calculation of brightness temperatures in the presence of precipitation; (c) perform multiple scattering brightness temperature calculations in precipitating conditions: an exact multiple scattering approach for fully polarized brightness temperature calculations has been included as a user selectable option described in Section 4.4. This option is applicable to the simulation of data from sensors with polarization discrimination; (d) perform statistical retrievals of relevant meteorological parameters based on RADTRAN simulations; and (e) assimilate user specified input profiles - standard meteorological profile models (e.g. U.S. standard, tropical, etc.) has been augmented by the capability to accept field data, radiosonde and other upper air data, and user specified format profile data as input.

With these enhancements and the algorithm upgrade described in Section 4.1, the AFGL RADTRAN transmittance/brightness temperature computer code provides a user friendly system simulation and retrieval tool consistent in purpose and format with other AFGL atmospheric transmittance models, but suited for those users with a special interest in the microwave/millimeter wave spectral region.

6.2 Recommendations

Our major recommendation concerns the current RADTRAN gas absorption formulation. Comparison with FASCODE, for example, does indicate a difference in the calculation of gas absorption coefficient. At the present time, however, it was decided not to modify the RADTRAN gas absorption models. This decision was based on a number of considerations including: (a) maintaining model consistency, (b) simplicity of the current approach, and (c) technical direction from AFGL.

In light of the requirements for accurate gas absorption calculations imposed by physical retrieval procedures, we recommend that future consideration should be given to replacing the current RADTRAN gas absorption approach with one similar to that employed in the FASCODE "LASER" option. This would employ a specialized microwave/millimeter wave absorption line parameter file for the region such as that used in the FASCODE "TEST" option and an improved layering approach. In addition to improving accuracy and efficiency of the model, the layering update would provide the additional benefit of making the multiple scattering option more efficient by reducing the number of layers treated within the precipitating cloud.

Finally, for the purpose of physical retrievals, a line-by-line approach such as RADTRAN is much too inefficient computationally to employ for extensive simulation studies. The line-by-line model, however, can be applied to the evaluation of appropriate "band model" coefficients to be applied for specific sensor channels. One approach for the microwave has recently been suggested by Eyre and Woolf (1988). It would be extremely useful to provide this code along with the RADTRAN line-by-line algorithm.

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